Overview of Extra Low ENergy Antiproton ring (ELENA) and TE-EPC contribution to the project

TE-EPC Group Meeting

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Introduction: Antiproton Decelerator

The Antiproton Decelerator (AD) provides low-energy antiprotons mainly for studies of antimatter. The starting point is a beam of protons from the Proton Synchrotron (PS), which is fired into a block of metal.

The antiprotons produced travel at almost the speed of light and have too much energy to be useful for making antiatoms. A ring of bending and focusing magnets keeps the antiprotons on the same track, while strong electric fields slow them down. Passing the antiprotons through clouds of electrons – a technique known as „cooling" – reduces the sideways motion and the spread in energies. Finally, when the antiprotons have slowed down to about 10% of the speed of light, they are ready to be ejected.

Most of the AD experiments need antiprotons with 3-5keV kinetic energy, which is significantly lower than the 5.3MeV beam extracted from AD. Today antiprotons are decelerated further down by sets of degraders. This results in poor efficiency and in the end less than 1% of AD beam can be trapped.

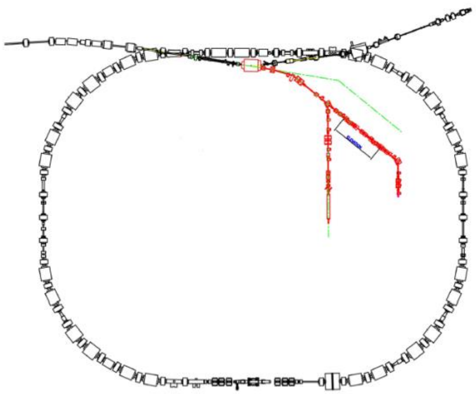
Introduction: ELENA

The Extra Low ENergy Antiproton ring (ELENA) is a CERN project aiming at constructing a small synchrotron to further decelerate antiprotons from the Antiproton Decelerator from 5.3MeV to 100keV and improve the trapping efficiencies of existing experiments by one to two orders of magnitude. Controlled deceleration in a synchrotron equipped with an electron cooler to reduce emittances in all three planes will allow the existing AD experiments to increase substantially their antiproton capture and render new experiments possible.

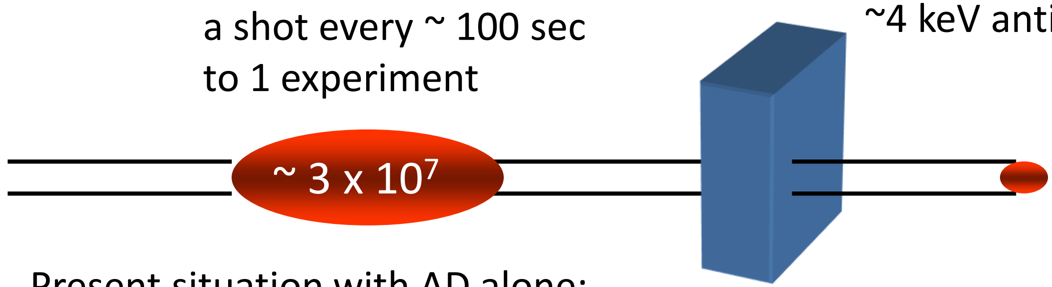
Electron cooling will be applied at an intermediate plateau and at the final energy. In addition to the increased number of antiprotons, ELENA will be able to deliver beams almost simultaneously to all four experiments resulting in an essential gain in total beam time for each experiment.

The AD experimental area layout will not be significantly modified, but the much lower beam energies require the design and construction of completely new electrostatic transfer lines.

Introduction: current and future status



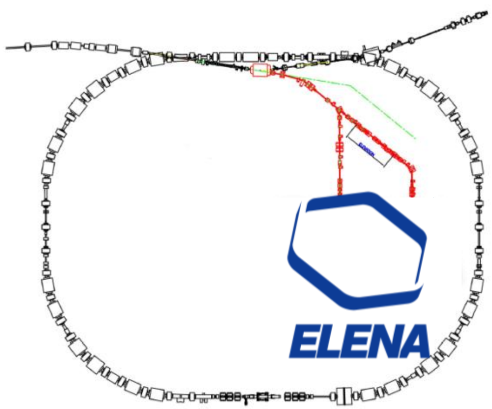
5.3 MeV antiprotons
a shot every ~ 100 sec
to 1 experiment



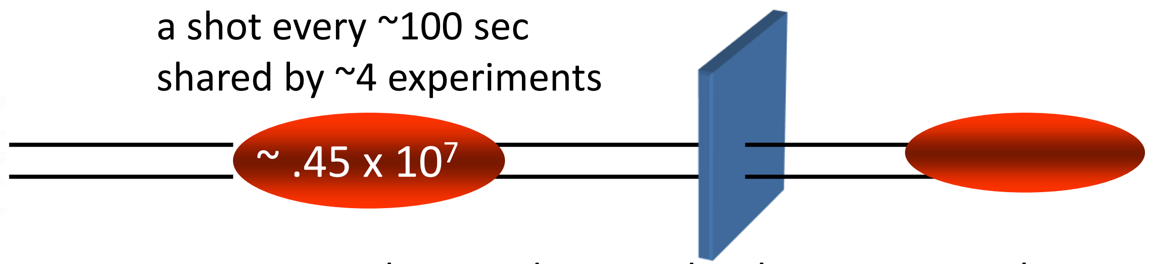
~4 keV antiprotons/~ 100 sec

Present situation with AD alone:

- experiments slow antiprotons down by „degrader”
- very inefficient method, most (>99%) antiprotons lost



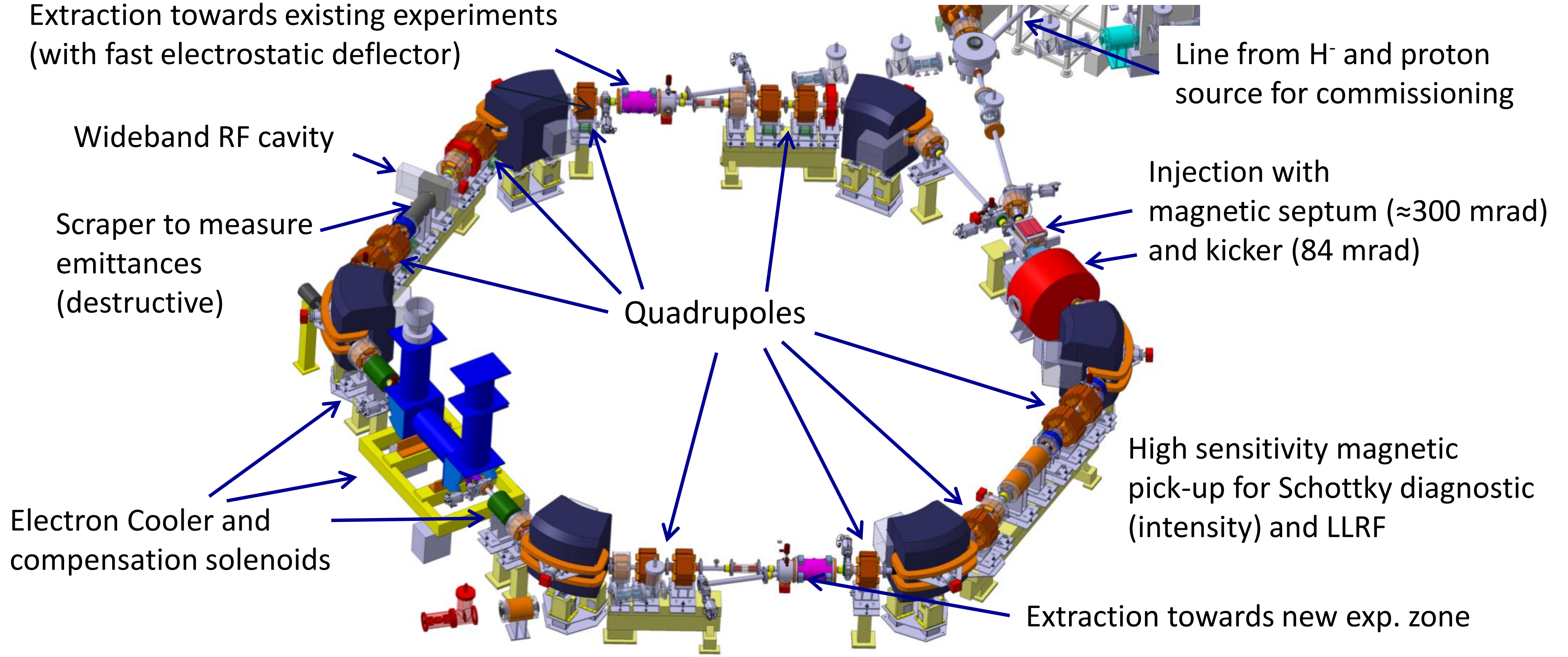
100 keV antiprotons
a shot every ~100 sec
shared by ~4 experiments



Future situation with AD and ELENA decelerating to 100 keV:

- thinner „degrader” and increased trapping efficiency (some experiments use other means to decelerate the beam)
- intensity shared by four experiments allows longer periods with beam

ELENA ring layout



- Deceleration of antiprotons from 5.3 MeV to 100 keV to improve efficiency of experiments
- Circumference of 30.4 m (1/6 the size of the AD)
  - Fits in available space in AD hall and allows installing all equipment without particular efforts

ELENA ring power converters

ELENA ring (excluding electron cooler), injection, extraction as well as source lines will be build out of 11 different types of elements (including electrostatic quadrupole correctors). TE-EPC is going to provide power converters for 46 magnets and 8 electrostatic assemblies (consisting of many electrostatic elements).

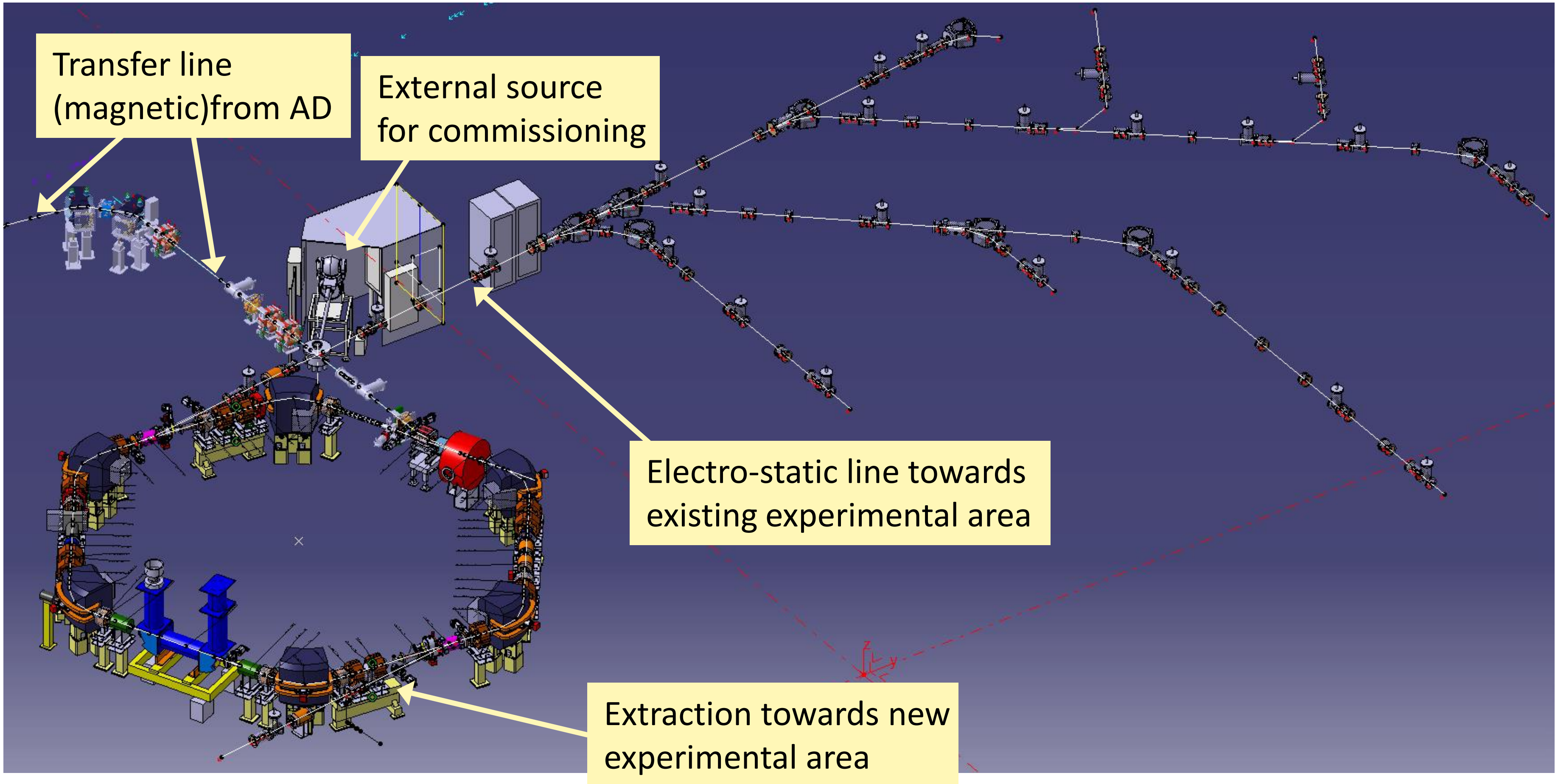
Element type	Element responsible	Element label	Element short label	Number of elements used	Number of elements powered by TE-EPC	Converter to be used
Bending magnet, horizontal	TE-MSC	PXMBHEKCWP	MBR	7	7	APOLO_2p
Quadrupole, normal	TE-MSC	PXMQNLGNAP	MQR	15	15	CANCUN_50
Sextupole, normal	TE-MSC	PXMXNADNAP	MXR	4	4	CANCUN_50
Quadrupole, skew	TE-MSC	PXMQSABNAP	MQS	2	2	CANCUN_50
Corrector H+V	TE-MSC	PXMCCAYWAP	MCR	24	24	CANCUN_50
Solenoid	TE-MSC	PXMLNAFNAC	MLR	2	2	CANCUN_50
Bending magnet, horizontal	TE-MSC	PXMBHCBCWP	MBL	2	2	COMBO-DELTA
Quadrupole, normal	TE-MSC	PXMQNAFNWP	QPMA	1	1	COMBO-DELTA
Septum magnet	TE-ABT	MSMIE	-	1	1	COMBO-DELTA
Kiker magnet	TE-ABT	MKKFH	-	1	0	-
Quadrupole corrector assembly	TE-ABT	ZQNA	-	8	8	CAEN/ISEG

Following number of converters is needed for operation (electron cooler not included) of the ring:

- 1 × APOLO_2p
- 34 × CANCUN_50
- 1 × COMBO-DELTA [420A; 45V]
- 1 × COMBO-DELTA [200A; 15V]
- 1 × COMBO-DELTA [1200A; 15V]
- 42 × HV channels

ELENA transfer lines

Due to the low energy of the beam, it is feasible to use optical elements that influence with the beam using an electric field rather than the traditional magnetic field. Several types of optical elements (deflectors, quadrupoles and correctors) are used to construct the geometry and optics of the ELENA transfer lines which total length is 95m.



ELENA transfer lines HV cassettes

The ELENA transfer lines use electrostatic elements to guide and deliver the beam to the experiments. All elements will be powered with DC high voltage power converters. The transfer lines have been designed for operation with three different voltage levels: 2 kV (correctors), 6 kV (quads), 12 kV (bending).

Since practically no current is required, small high voltage power sources can be used to power these elements.

Converter type	Circuit	Qty total	Qty phase 1	Qty phase 2	Mode of operation
QUAD_POS	Electrostatic Quadrupoles	66	15	51	DC
QUAD_NEG	Electrostatic Quadrupoles	66	15	51	DC
COR_POS	Electrostatic Correctors	62	22	40	DC
COR_NEG	Electrostatic Correctors	62	22	40	DC
BEND_POS	Electrostatic Slow Deflectors	11	0	11	DC
BEND_NEG	Electrostatic Slow Deflectors	11	0	11	DC
ION_POS	Ion Switch	1	1	0	DC
ION_NEG	Ion Switch	1	1	0	DC
	Total Operation	280			

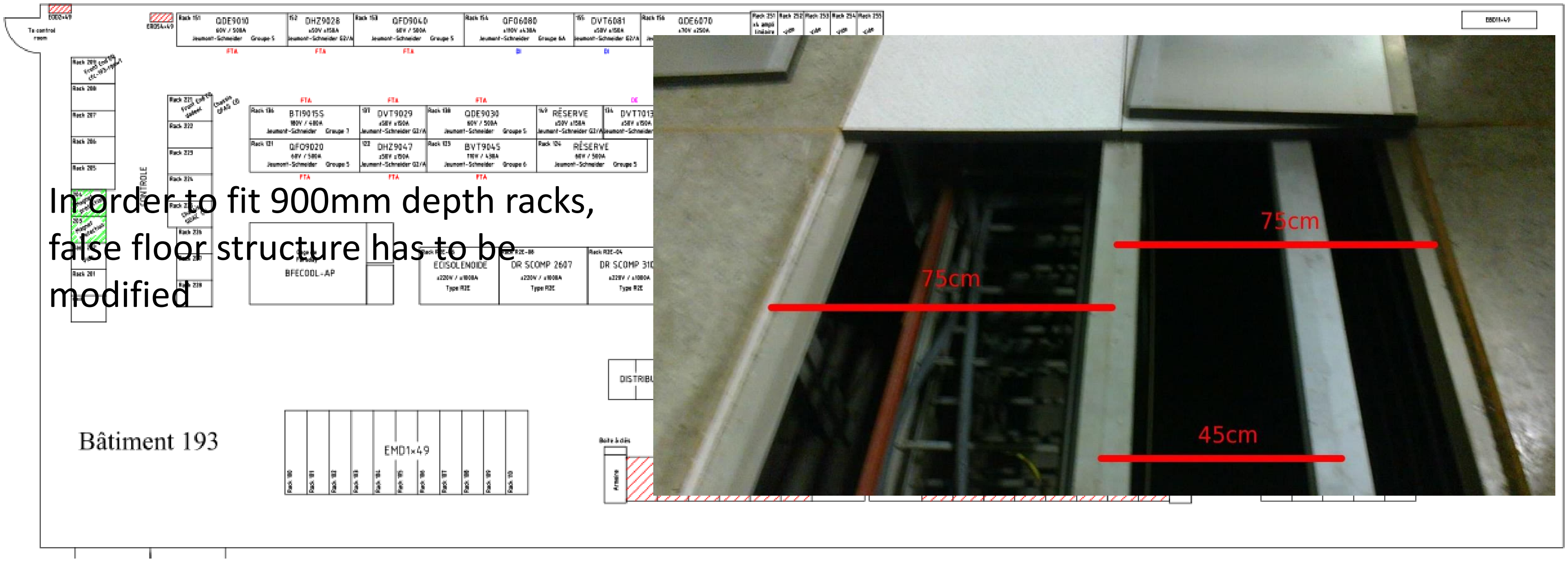
ELENA transfer lines HV cassettes

A system based on high voltage multichannel boards mounted on a chassis system has been selected to power the circuits of the electrostatic elements of ELENA transfer lines. Different vendors have been evaluated taking into account electrical performance, control system, and integration.

Up to 10 boards can be mounted in each chassis system, which can be mounted in universal 19’’ racks. A cooling system based on fans is provided and controlled by CPU.

All TE-EPC equipment will be installed in the building 193 or within the AD ring. The following types of power converters will be located in the AD powering room:

- APOLO_2p
- CANCUN_50

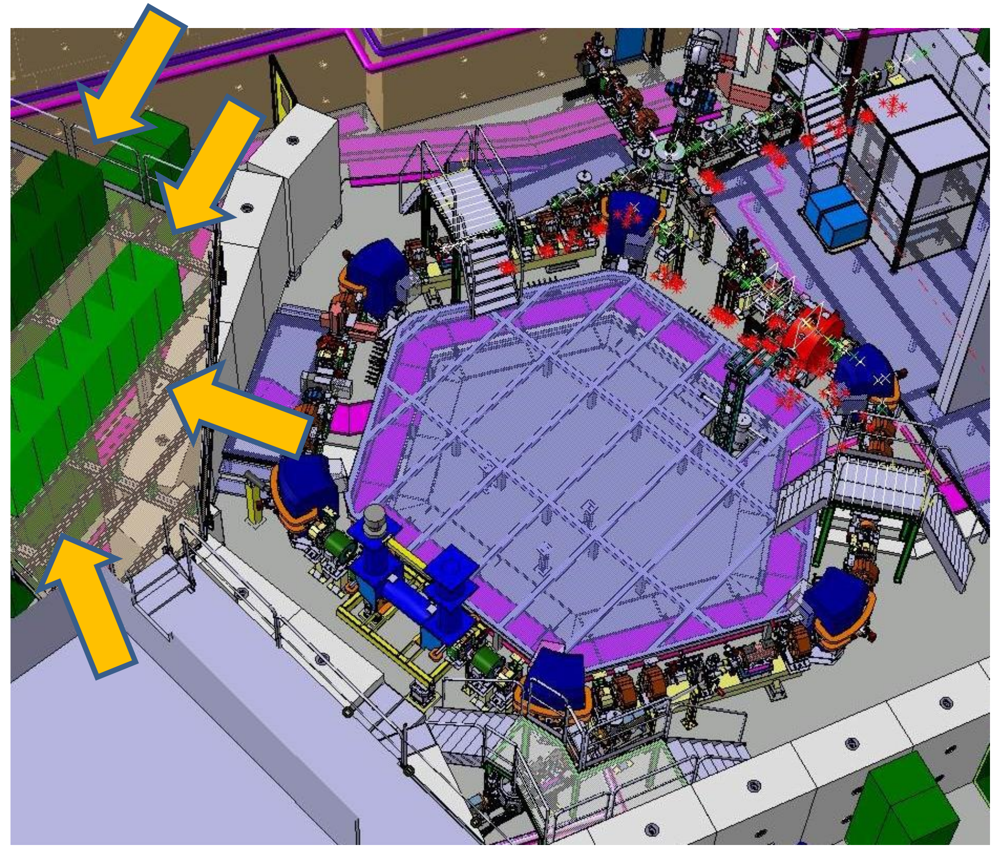


In order to fit 900mm depth racks, false floor structure has to be modified

Power converters location

Upper platform near the ELENA ring is suitable only for racks with **depth 800mm** and it is reserved for the HV power converters and power converter which are delivering high current (> 100A). The APOLO_2p could not be placed in this location as the depth of the rack is 900mm and the weight of the converter is 1.8T surpassing that supported by the structure (500kg). The following types of power converters are going to be put on the platform:

- HV power converters
- 1 × COMBO-DELTA [420A; 45V]
- 1 × COMBO-DELTA [200A; 15V]
- 1 × COMBO-DELTA [1200A; 15V]



ELENA budget

Total cost of the project equals to 26MCHF, from which CERN's contribution is 22.94MCHF. In order to facilitate the management of the project, one work package (WP) was created for each deliverables that has to be provided by groups around CERN. The ELENA WP 2.4 belongs to TE-EPC and it is splitted into 7 smaller sub-work packages.

Activity	Expenses total [CHF]
ELENA WP 2.4.1 – CANCUN Power Converters	383 000
ELENA WP 2.4.2 – Commercial Low Power Converters	160 000
ELENA WP 2.4.3 – APOLO Power Converters	253 000
ELENA WP 2.4.4 – HV Power Converters	400 000
ELENA WP 2.4.5 – Controls for HV Power Converters	100 000
ELENA WP 2.4.6 – Power Converter Control Electronics	307 000
ELENA WP 2.4.7 – High Precision Measurements (DCCTs)	45 500

Total amount of money assigned to TE-EPC for ELENA project is **1 648 500CHF**.

More detailed information concerning the budget can be found under the following address https://issues.cern.ch/browse/EPCCCS-2032

ELENA schedule

Installation of the ELENA ring and all lines required for commissioning of the ring is planned during the second half of 2015 and beginning of 2016.

First phase of ELENA commissioning is foreseen for May 2016. Its goal is to commision the ring with injection and extractions lines using external source of particles.

After the first phase, the existing magnetic transfer lines from the AD to the experiments will be removed and new electrostatic lines from ELENA installed and commissioned during the first half of 2017.

The first physic run with 100keV antiprotons from ELENA is foreseen during the second half of 2017.

Conclusions

- With the current set-up, most of the antiprotons produced in AD are lost due to deceleration from the extraction energy
- ELENA is a small synchrotron with electron cooler to further decelerate antiprotons from the AD from 5.3MeV to 100keV
- It will improve efficiency of experiments trapping antiprotons by 1 to 2 orders of magnitude
- It will allow new types of experiments
- ELENA will provide beam to several experiments simultaneously (lower intensities)
- First antiproton physics with ELENA planned in 2017 (2^{nd} half)

Thank you for your attention!

Basic ELENA parameters

Parameter	Value	Comment
Basic shape	Hexagonal	two long straights for injection and cooling
Periodicity	Two periods	neglecting the electron cooler
Circumference	30.4055 m	1/6 the AD
Max. beta functions $\beta_{H,max}$/ $\beta_{V,max}$	≈12 m/≈ 6m	
Working point Q_H/Q_V	≈2.3/≈1.3	some tuning range to choose working point
Relativistic gamma at transition	≈2	
Energy range	5.3 MeV – 100 keV	
Momentum range	100 MeV/c – 13.7 MeV/c	
Transverse acceptances	75 μm	
Cycle length	>25 s	deceleration and cooling
Repetition rate for pbar operation	≈100 s	limited by AD operation
Injected intensity	$3\ 10^7$ antiprotons	
Efficiency	60%	conservative guess
Parameter at ejection		with bunched beam cooling
Number of bunches	4	baseline with four bunches
Bunch population	$0.45\ 10^7$ pbars	
Rel. mom. spread	$0.5\ 10^{-3}$	Rms value
Bunch length	75 ns	Rms value
Hor. emittance	1.2 μm	Rms, physical
Vert. emittance	0.75 μm	Rms, physical