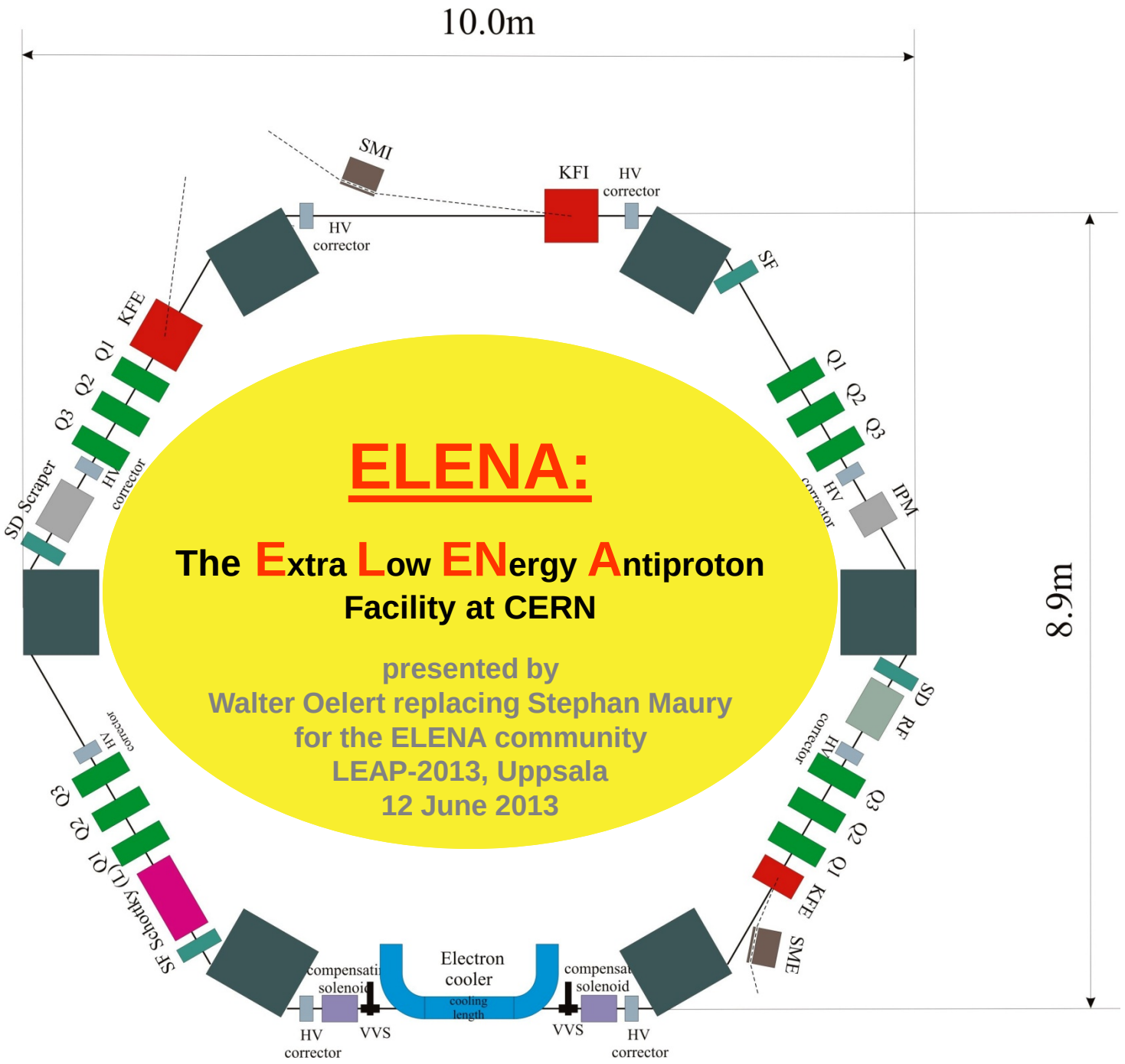
10.0m
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ELENA:
The Extra Low ENergy Antiproton Facility at CERN
presented by
Walter Oelert replacing Stephan Maury
for the ELENA community
LEAP-2013, Uppsala
12 June 2013

A SMALL DECELERATION RING FOR EXTRA LOW ENERGY ANTIPROTONS (ELENA)

H. Herr

CERN, Geneva, Switzerland

Workshop on Physics at LEAR with Low Energy Cooled Antiprotons Erice, May 9 – 16, 1982

ABSTRACT

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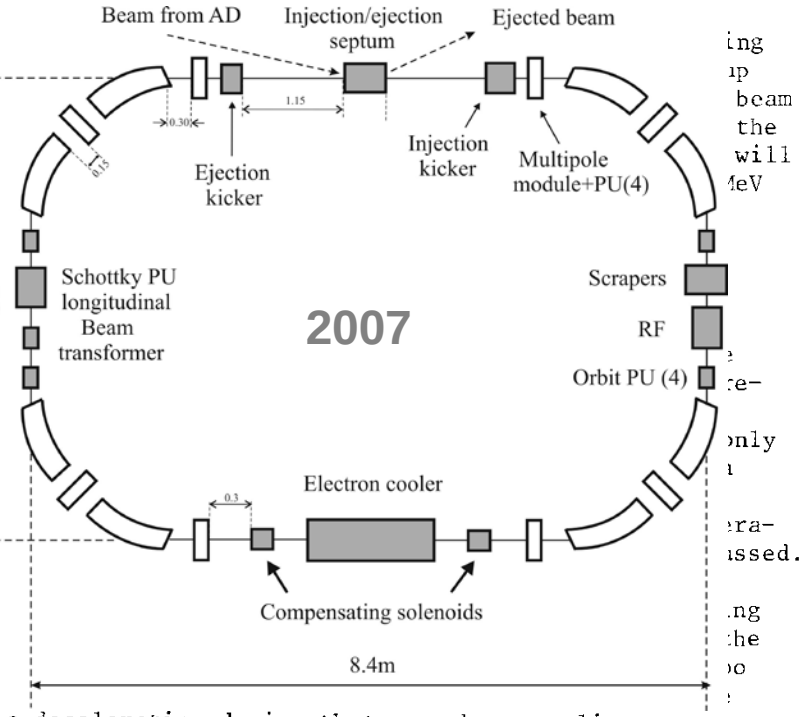

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INTRODUCT

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overcome by a deceleration device that uses beam cooling to compensate the increase of the phase space. In the following, a small and relatively inexpensive deceleration ring equipped with electron cooling[2,3] is presented; it can decelerate antiprotons coming

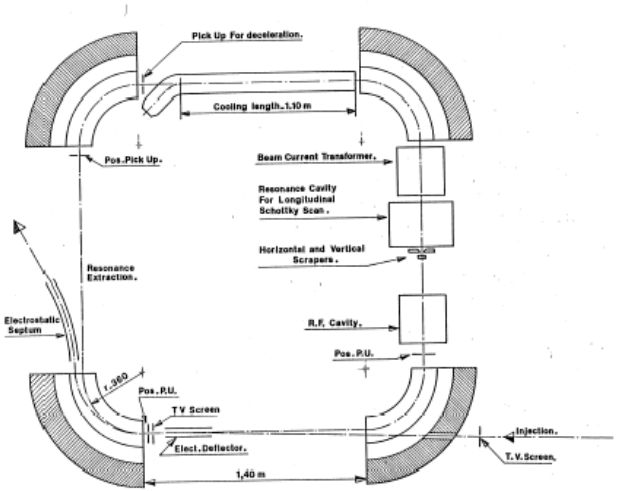


Fig.1

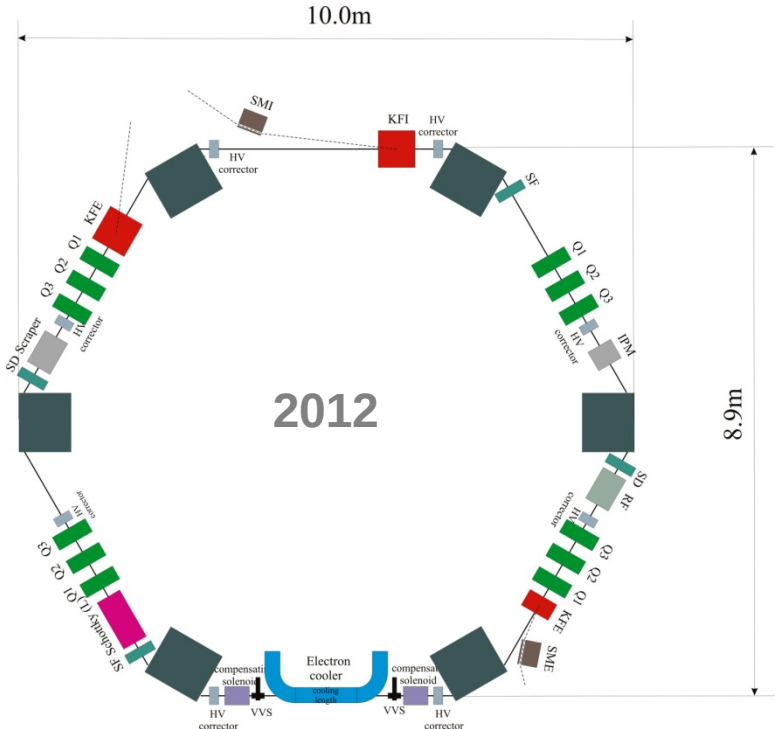
ELENA is a small decelerator which:

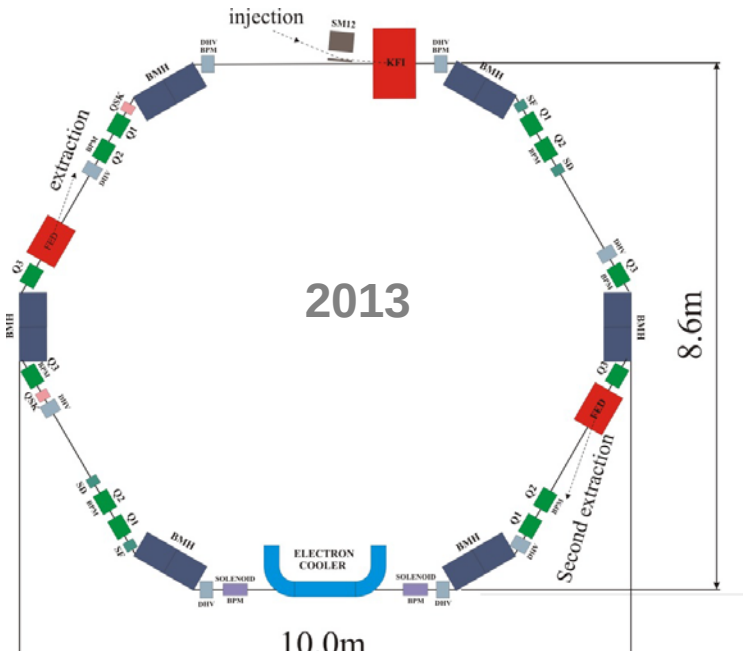
a) slows the AD antiprotons to 100 keV
b) cools them via integrated electron cooling
c) delivers the $\bar{p}$'s to the various experiments via electrostatic beam lines
d) allows optional for an additional experimental zone

input acceptance of ELENA matches the AD emittance

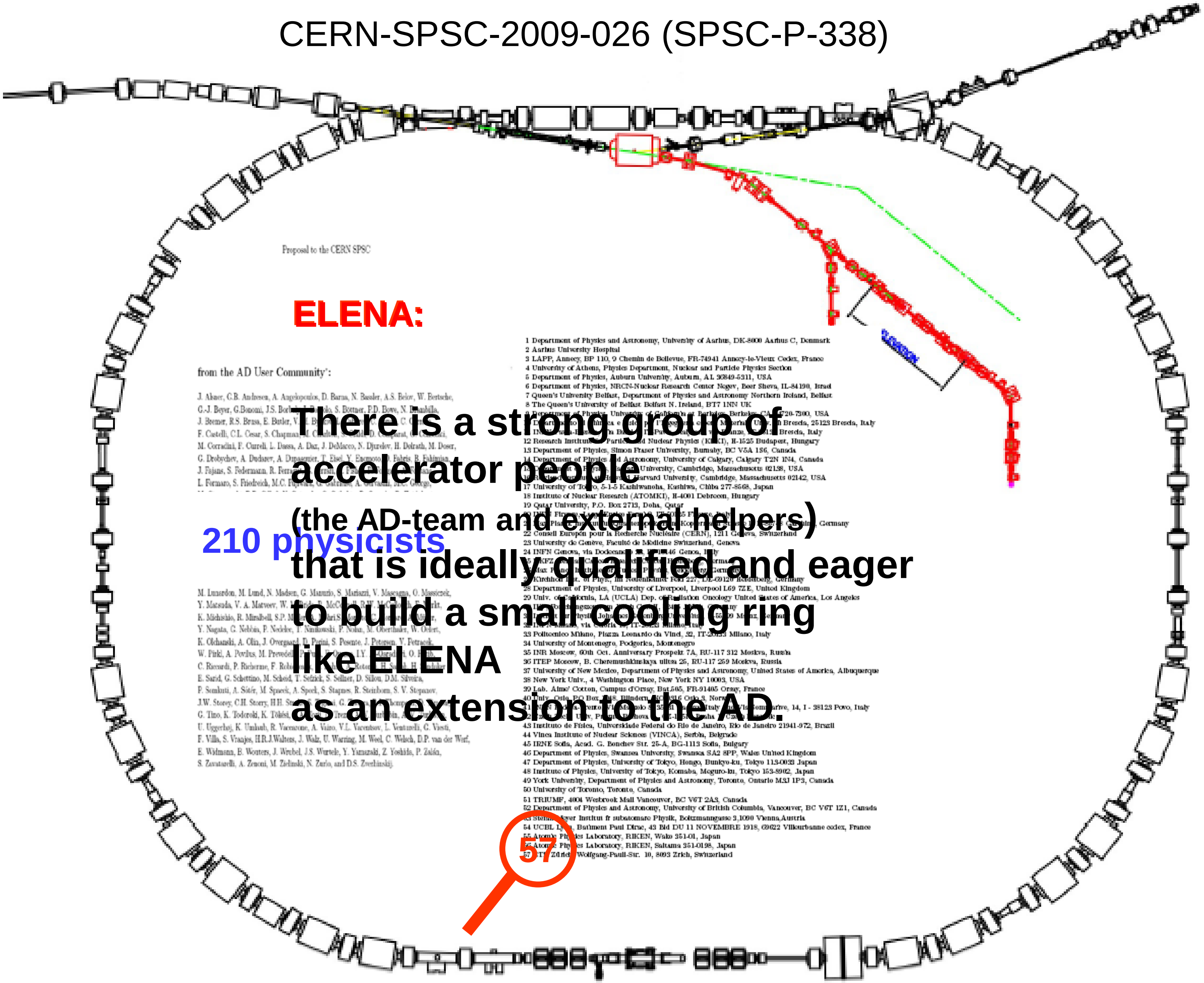
electron cooling guarantees for high quality beam

ELENA can be located within the present AD hall





CERN-SPSC-2009-026 (SPSC-P-338)

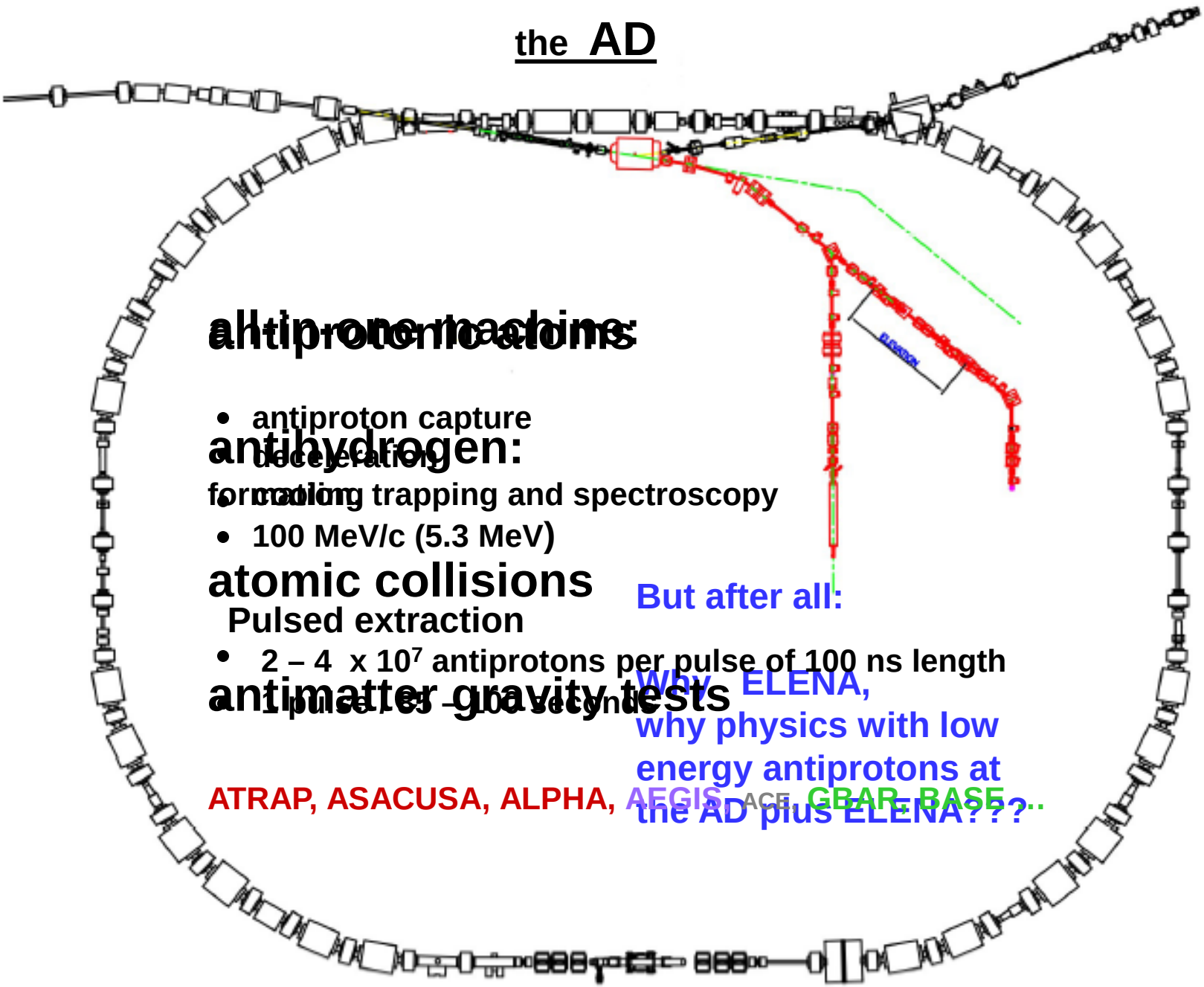


ELENA:

210 physicists

There is a strong group of accelerator people
(the AD-team and external helpers)
that is ideally qualified and eager to build a small cooling ring like ELENA as an extension to the AD.

the AD



all in one machine:

antiproton – matter interactions

- antiproton capture
- deceleration
- cooling

antihydrogen:

formation trapping and spectroscopy

- 100 MeV/c (5.3 MeV)

atomic collisions

Pulsed extraction

- 2 – 4 x 10^7 antiprotons per pulse of 100 ns length
- 1 pulse every 100 seconds

antimatter gravity tests

ATRAP, ASACUSA, ALPHA, AEGIS, ACE, GBAR, BASE...

But after all:

Why ELENA,
why physics with low energy antiprotons at the AD plus ELENA???

***General Motivations*:**

In the antimatter regime
presently established predictions (SM – GR) are experimentally not verified

The SM-extensions* govern a large set of emerging effects
relevant for low-energy antimatter physics experiments

e.g.: the baryon — antibaryon asymmetry in the Universe is NOT understood

standard explanation:	**alternate explanation:**
CP violation	CPT violation
violation of baryon number	violation of baryon number
thermodynamic non-equilibrium	thermodynamic equilibrium

New phenomena and new interactions might most likely be only observed at:

a) high energies: as at the LHC
b) extreme precisions: as at the AD

} that both is what CERN stands and is famous for in the world

One should investigate such fundamental phenomena and interactions
in the few places where we have the chance to do so very precisely
and for the antimatter research it is only and uniquely CERN

* see e.g. invited talk by Russell at the LEAP-05 conference

Makoto Kobayashi, 2008 Nobel laureate

I think the probability of discovering the CPT violation is tiny … ($1/\infty$)

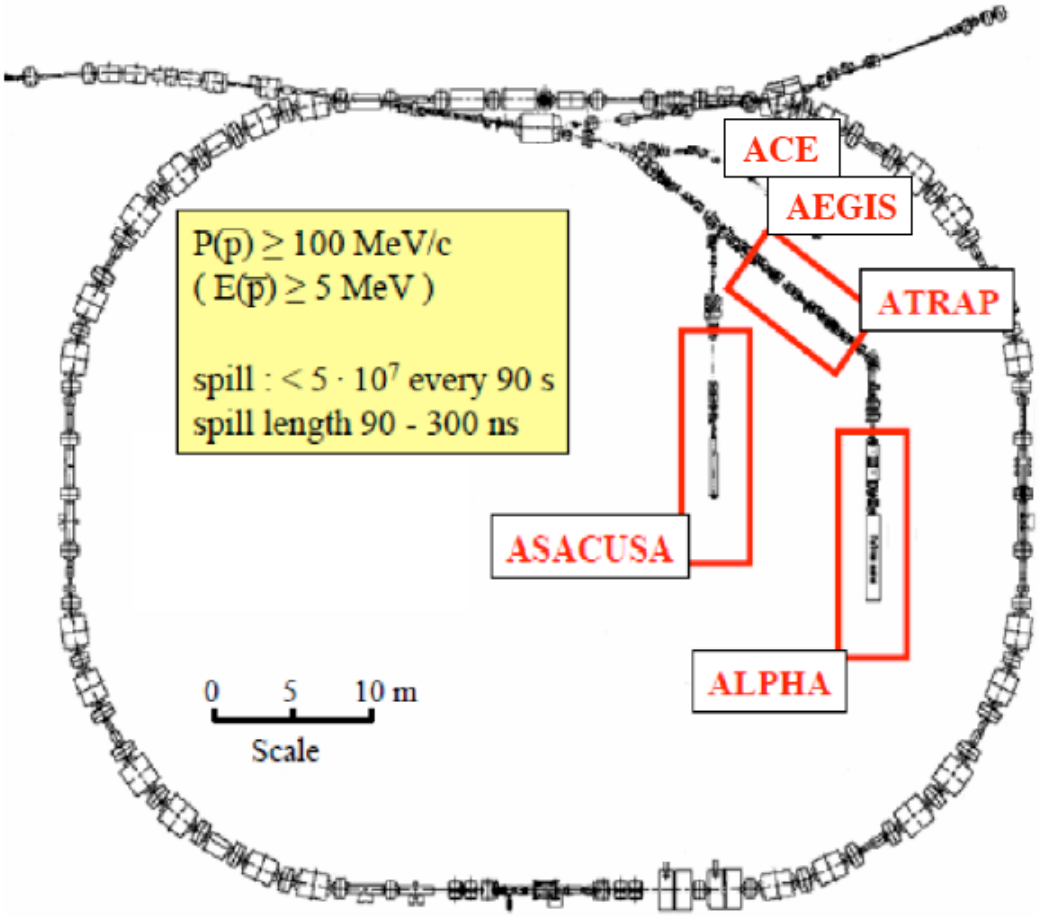
but the impact of such a discovery is ∞

$\frac{1}{\infty} \times \infty = ?!$ worth doing

Ryu Hayano

Klaus Jungmann at the workshop "New Opportunities in the Physics Landscape at CERN"

Antiproton Decelerator (AD) @ CERN



- **Started operation** July 6, **2000**

  Antiproton capture, deceleration, cooling
- **Pulsed extraction**
- **Many Experiments**
  - ASACUSA
  - ATRAP
  - ALPHA
  - AEGIS
  - Free Fall
  - PAX
  - ACE
  - .....
- **Request for more and better antiproton beams**
  - To speed up progress
  - To boost accuracy

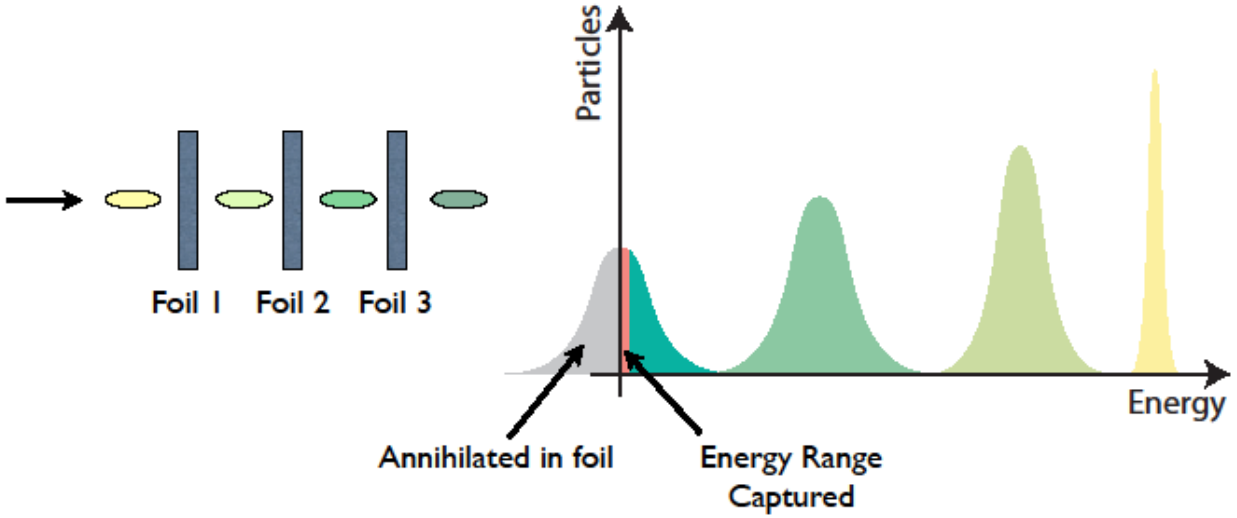
⇒ **ELENA**

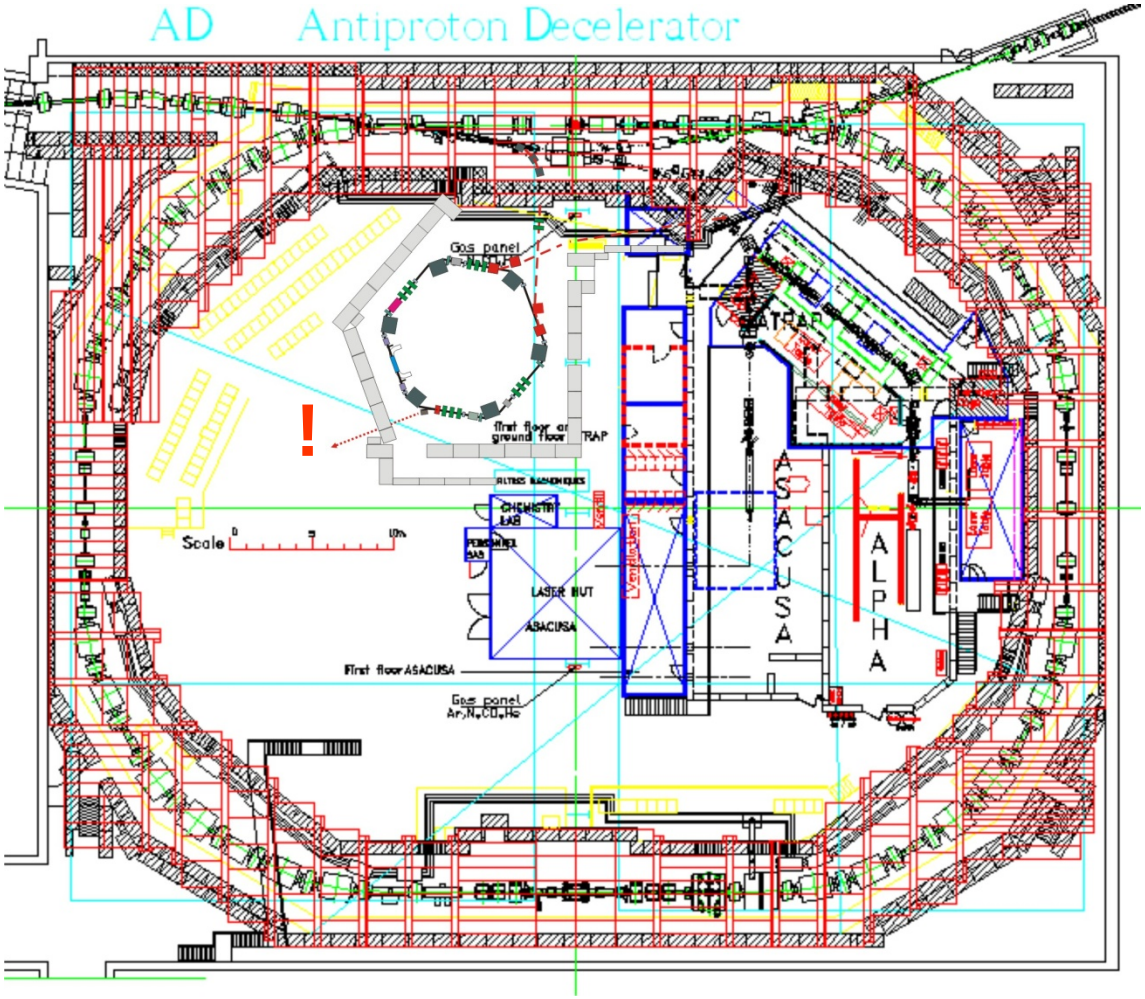
Motivation to build ELENA

- Most of AD experiments need antiprotons of 3 keV to 5 keV kinetic energy,

while AD produces them at 5.3 MeV.

- Further deceleration is done with degrading foils where particles lose energy and straggle
- Only 0.3% of antiprotons are captured into trap





CERN-BE-2010-029 OP

Technical Design Report in preparation

ELENA TDR:

1. **Introduction**
2. **ELENA overview**
3. **ELENA lattice**
4. **Beam Dynamics**
5. **Magnets**
6. **Radiofrequency system**
7. **Beam cooling system**
8. **Vacuum**
9. **H- and proton source**
10. **ELENA injection, extraction and transfer lines**
11. **Experimental areas**
12. **Controls**
13. **Beam diagnostics**
14. **Power converters**
15. **B-Train system**
16. **Safety**
17. **Other services**
18. **Operation**
19. **Civil Engineering**
20. **Cost, manpower, planning**
21. **Annex** (parameter list)
22. **References**

Review

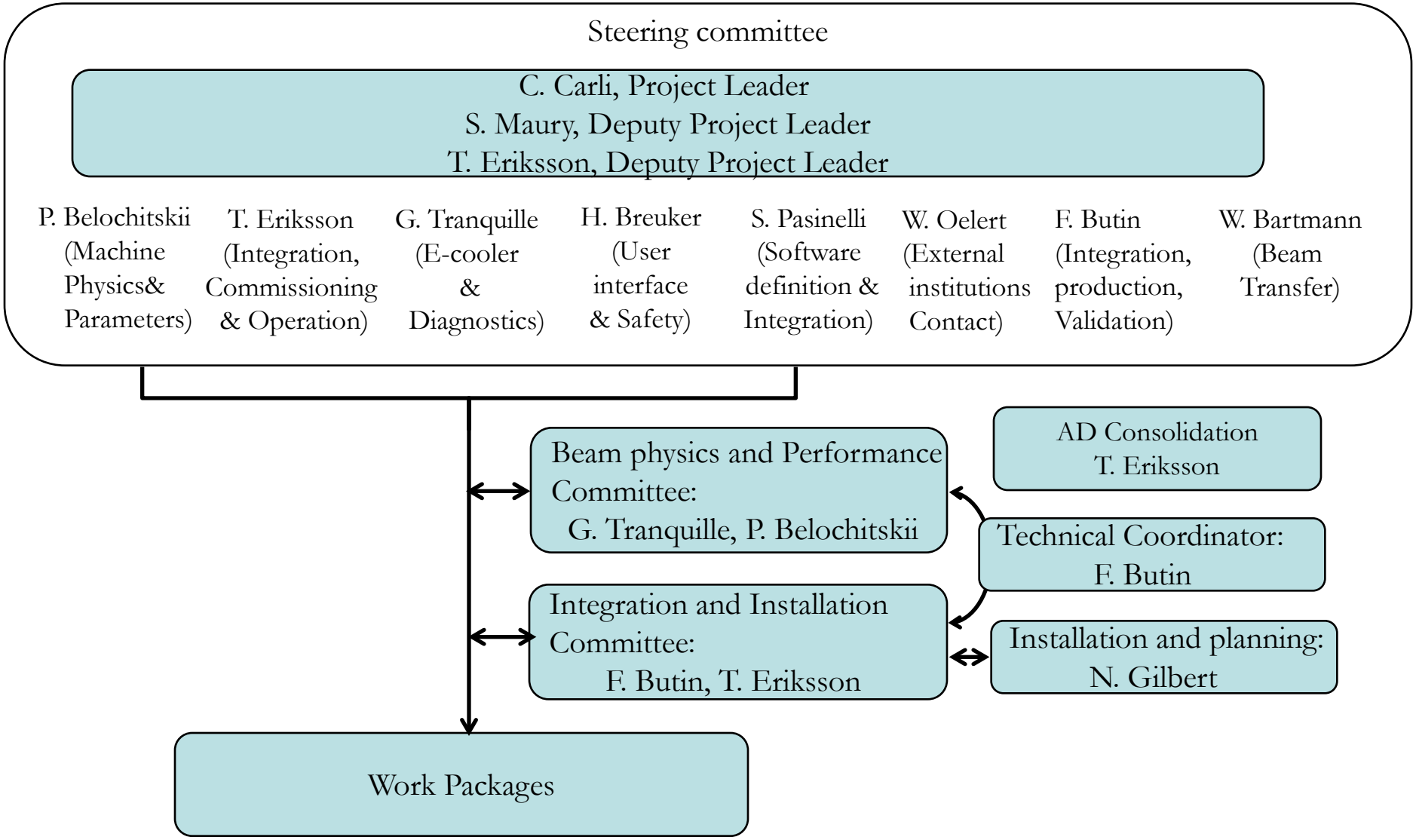
Present the ELENA project to specialists with experience in the field such that they can get a comprehensive overview.

The committee members will express their opinion on our plans, the feasibility of the project (technical issues, but as well planning and cost), possible issues and showstoppers, we may have overlooked, and provide advice for improvements and possible further studies. A list with specific questions should be provided from our side.

The proposed preliminary program comprises 15 presentations. Two full days should be foreseen for presentations and closed sessions of the committee.

Date: 2nd half of September 2013.

ELENA Project Structure



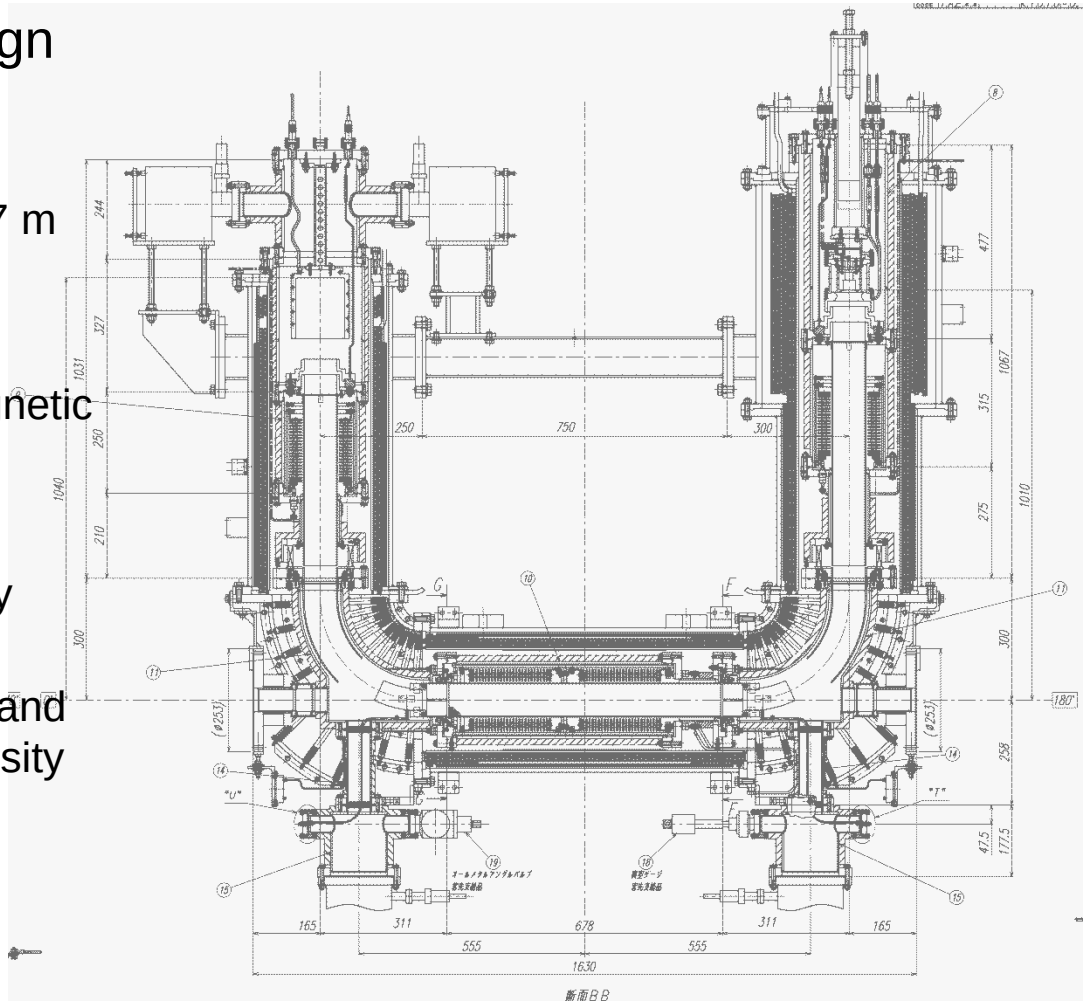
ELENA main parameters (to be confirmed by TDR)

Momentum range, MeV/c	100 - 13.7
Energy range, MeV	5.3 - 0.1
Circumference, m	30.4
Intensity of injected beam	3×10^7
Intensity of ejected beam	1.8×10^7
Number of extracted bunches	
Emittances (h/v) at 100 keV, π·mm	
Δp/p before extraction (bunched be	
Bunch length at 100 keV, m / ns	
Required (dynamic) vacuum, Torr	

Electron Cooling

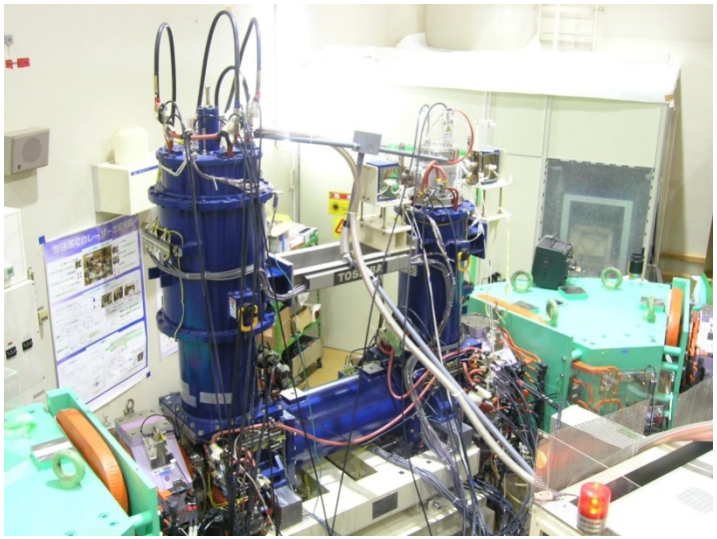
Hardware

- Based on S-LSR (Kyoto) design
  - To be constructed by Toshiba as the S-LSR cooler
  - Interaction (drift) increase to 1.07 m
  - New gun & collector design
  - Lower electron energy
  - Larger expansion and lower magnetic field in interaction regions
- Status
  - Electron cooler as contribution by University of Tokyo
  - Discussions on technical details and organization ongoing with University Tokyo and Toshiba



Sketch of the S-LSR Electron Cooler

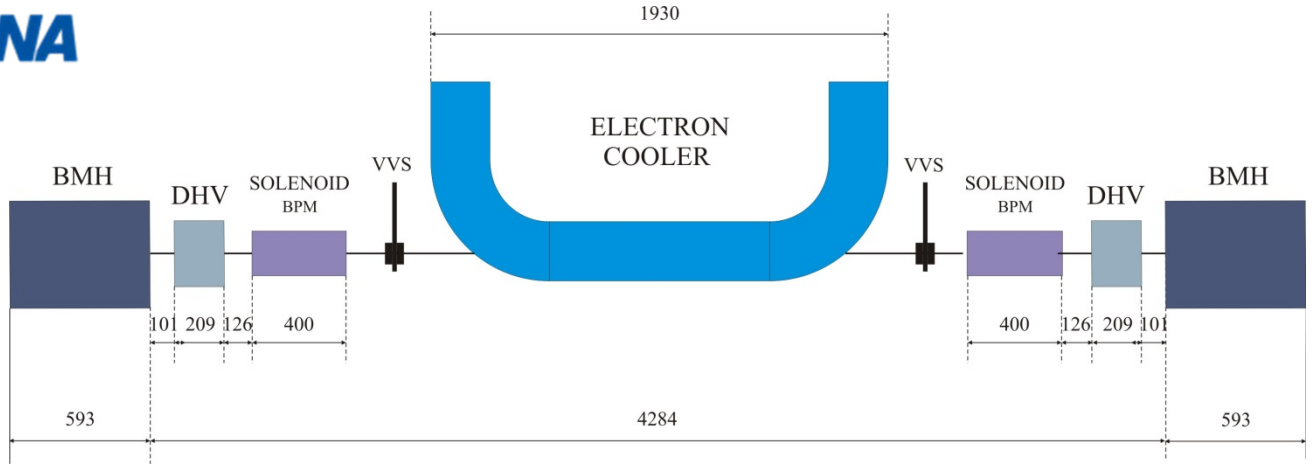
Meeting 9th May 2013 with the representatives of Toshiba Corporation for the procurement of the ELENA electron cooler



Various technical design issues, scheduling, and preliminary discussions toward preparing a cost estimation for the electron cooler were unofficially discussed. Some issues remain for further discussion.

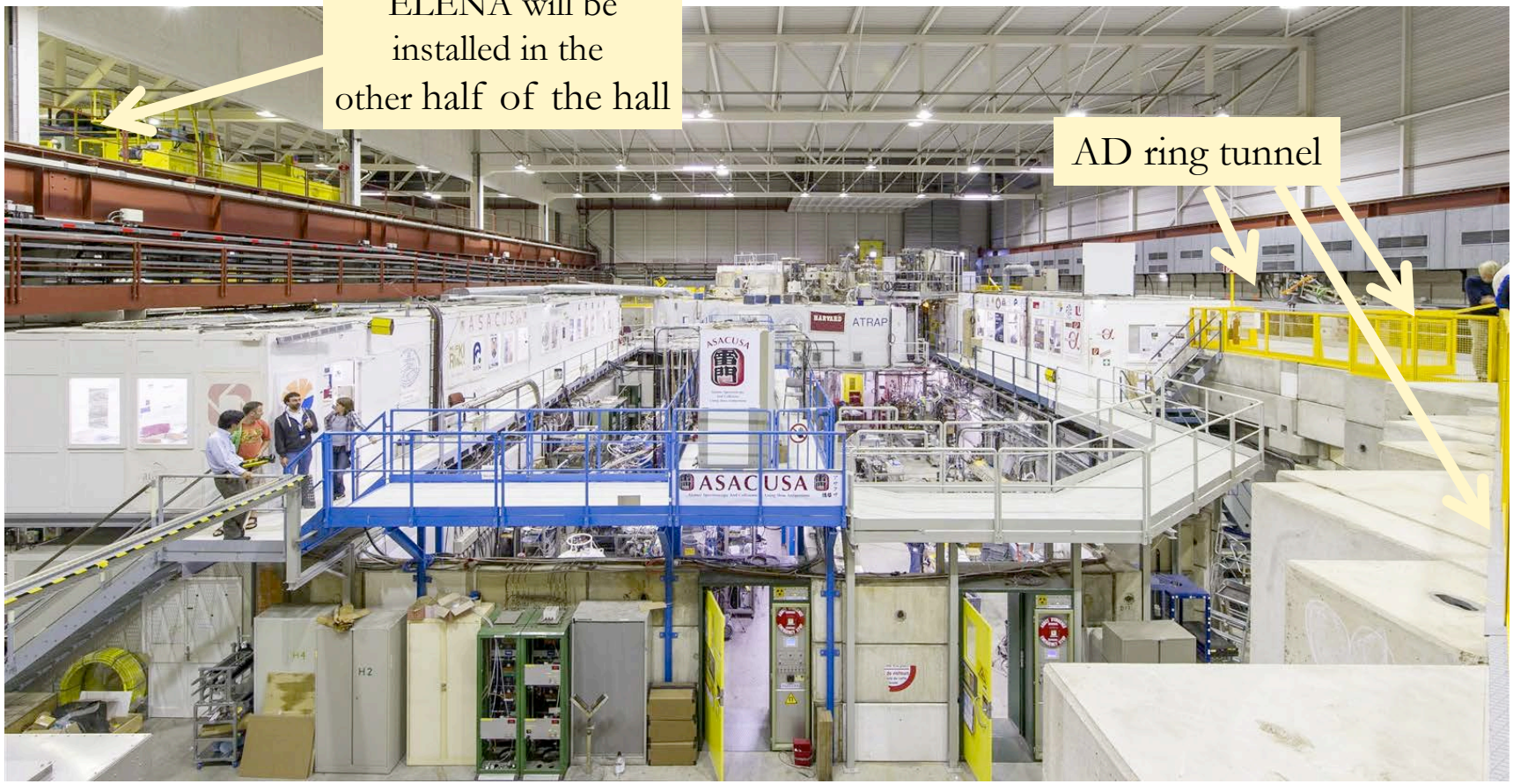
Toshiba has built 4 electron coolers : TARN II
KEK electron target
NIRS
Kyoto (s-LSR)

Electron cooler



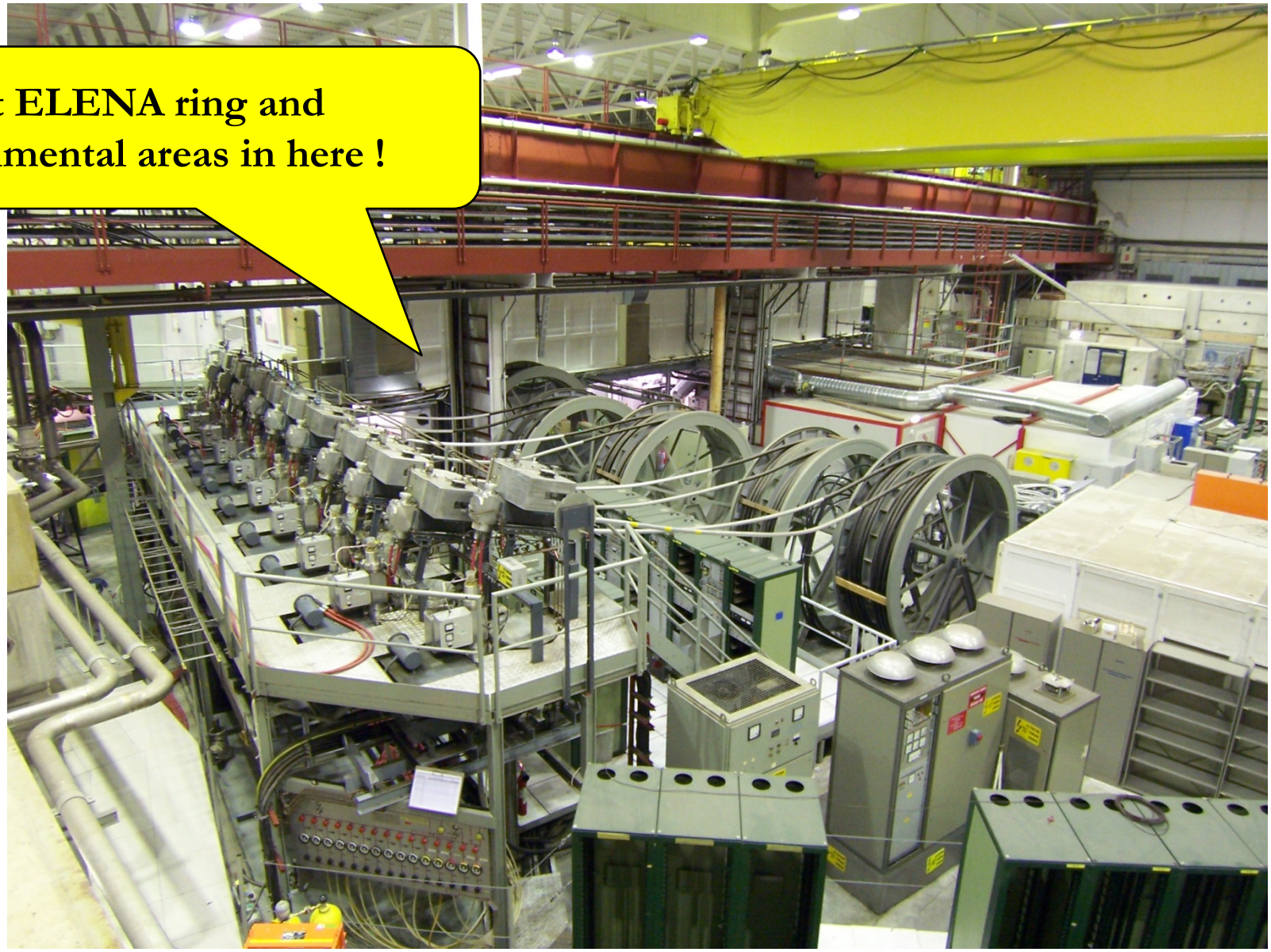
Cooling length l_c, m	~0.8
Beam cooled at momentum, MeV/c	35 & 13.7
Electron beam current I_e, mA	5 & 2
Cathode voltage at 35 MeV/c and 13.7 MeV/c, V	355 & 55
Nominal/maximal magnetic field in solenoid, G	100/500
Electron beam radius at 35 MeV/c and 13.7 MeV/c, mm	25

AD Low Energy Antiproton Facilities



– AD experiments in the AD hall (half of hall with experiments shown)

Main Integration Challenge



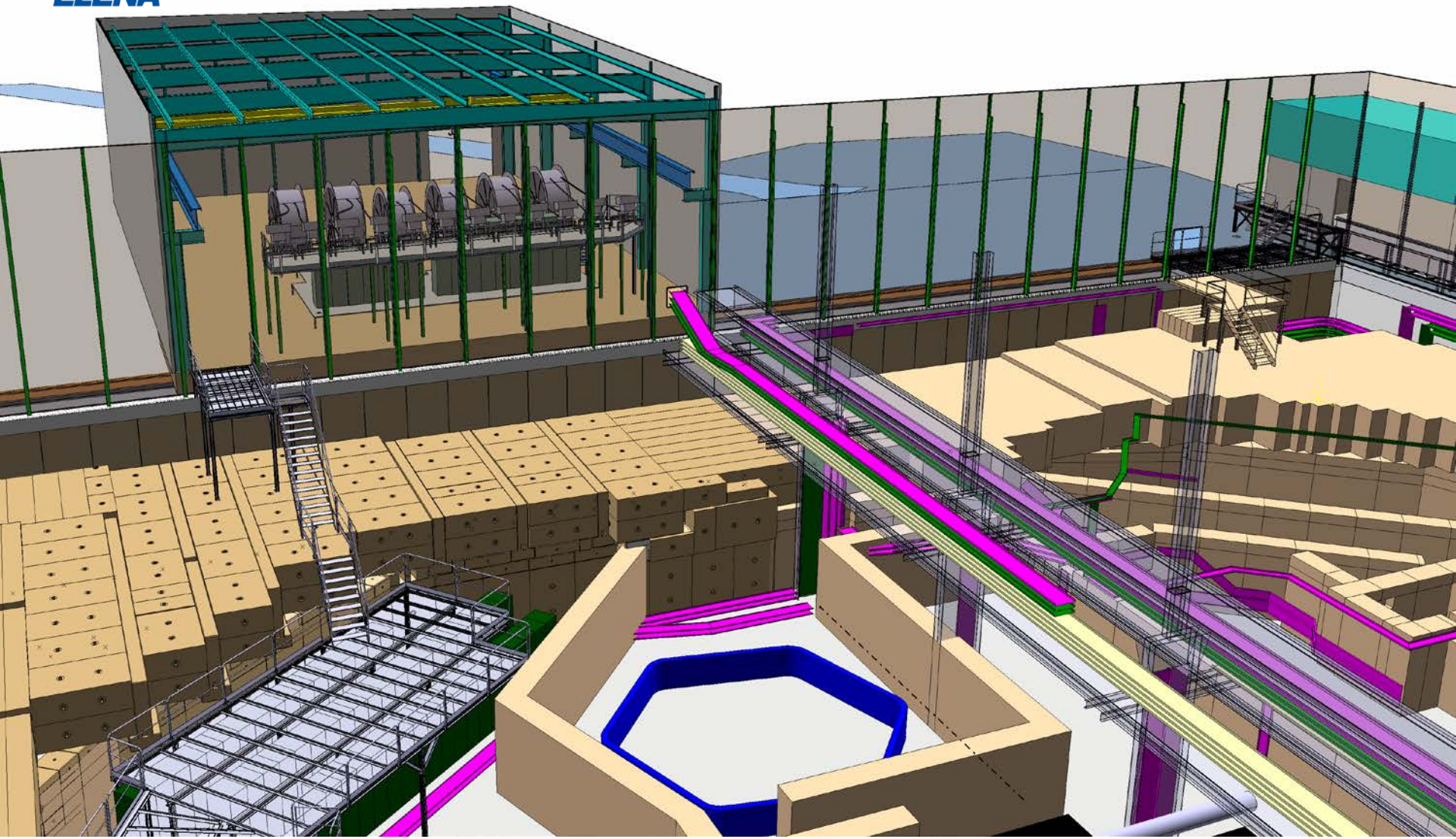
New Building

The new building is multipurpose:

- Short storage for existing and future experiments
- Magnetic horn test bench
- AD and ELENA kickers
- Workshop for the experiments

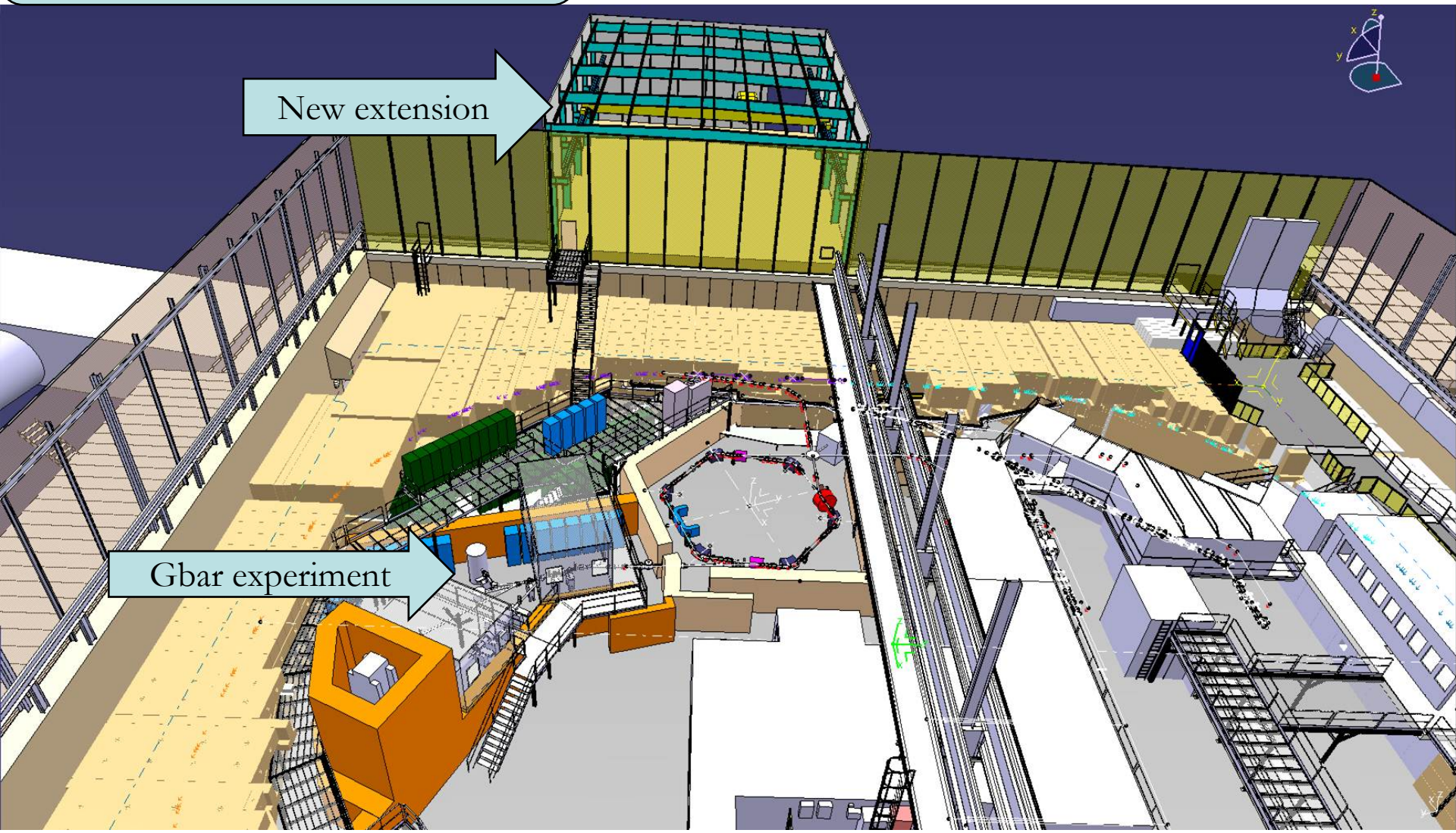
This will give space for ELENA machine and for existing/new antiproton experiments.

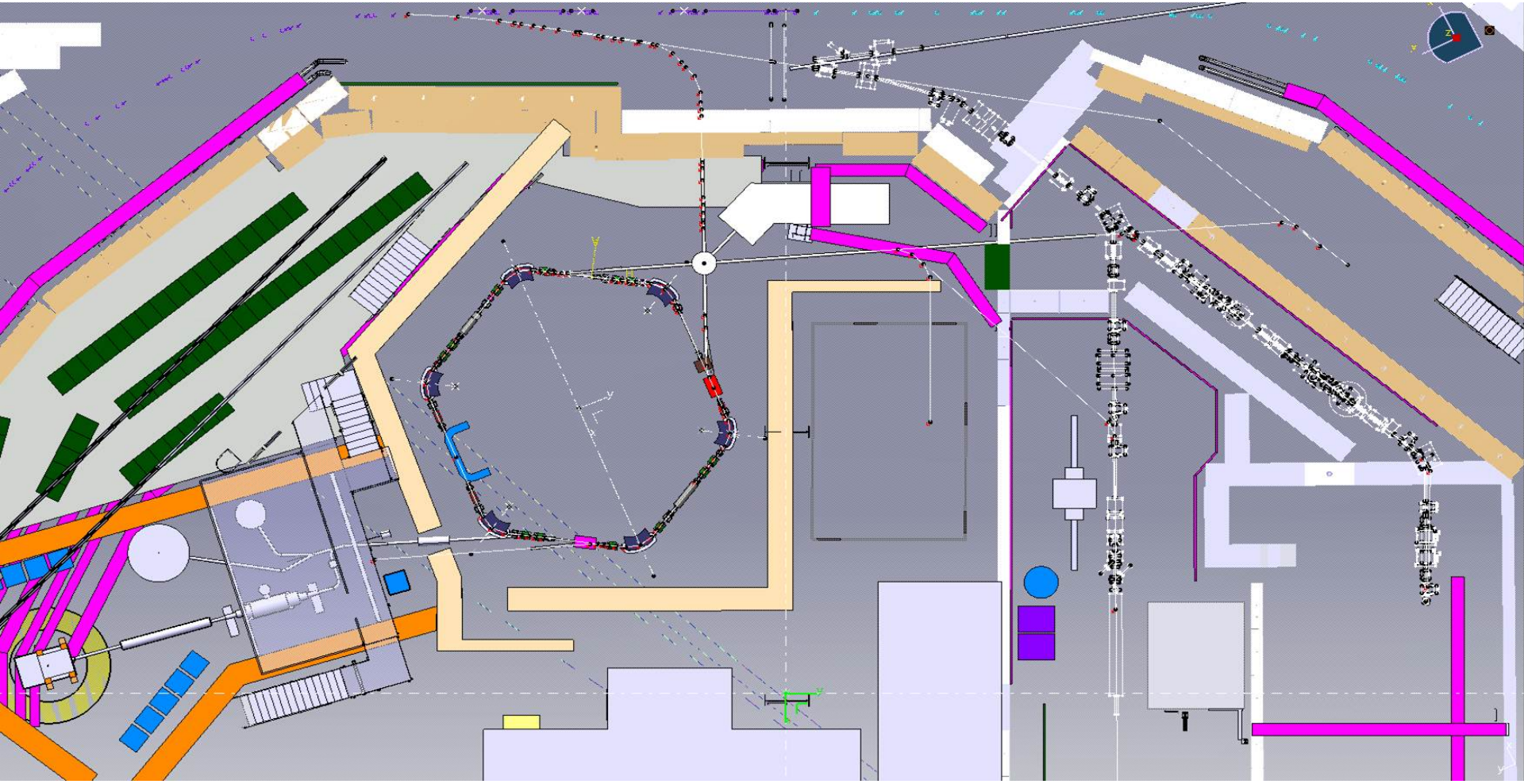
ELENA

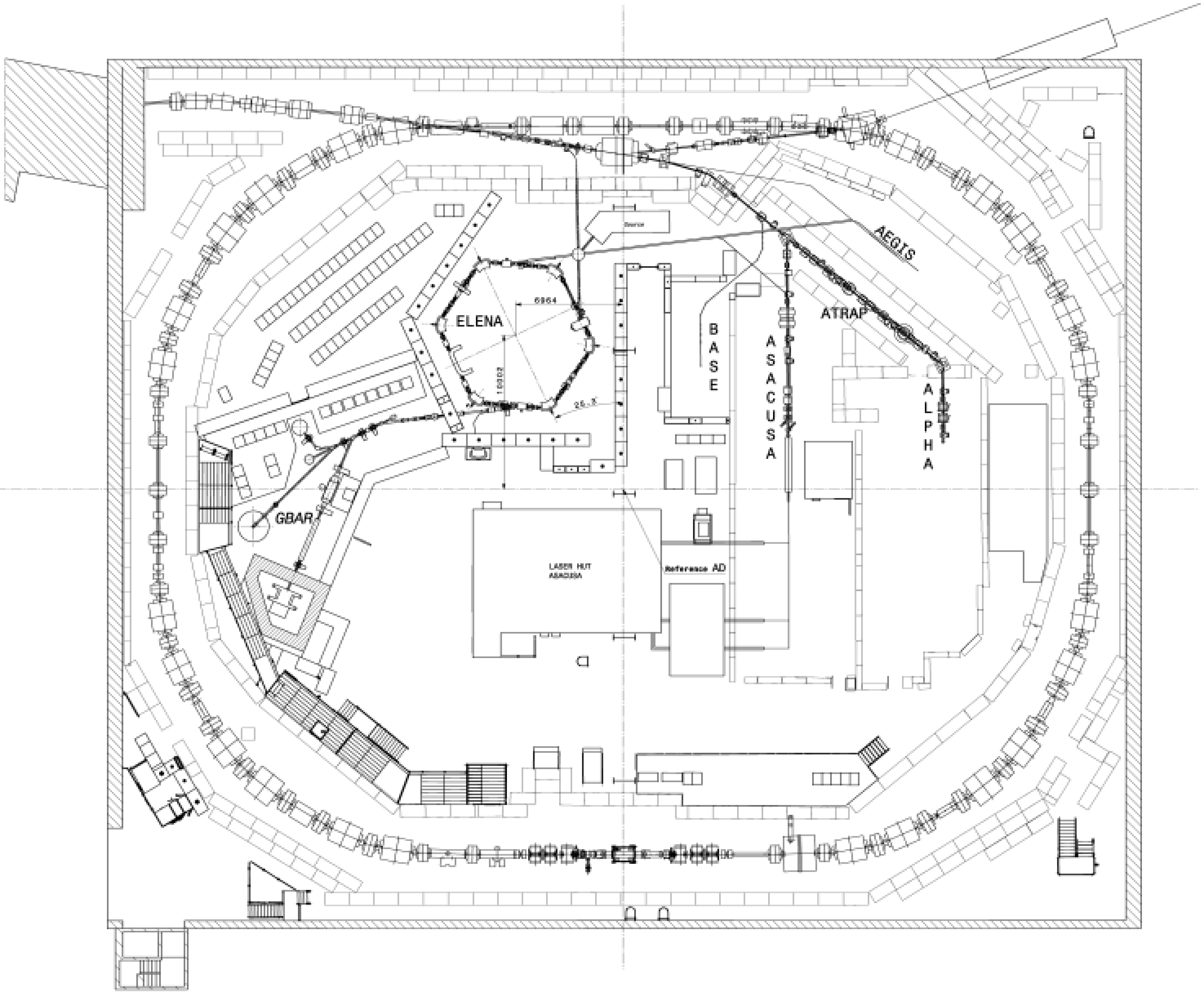


by A. Kosmicki and L. Lopez

ELENA







NOTA : The transfer lines comes
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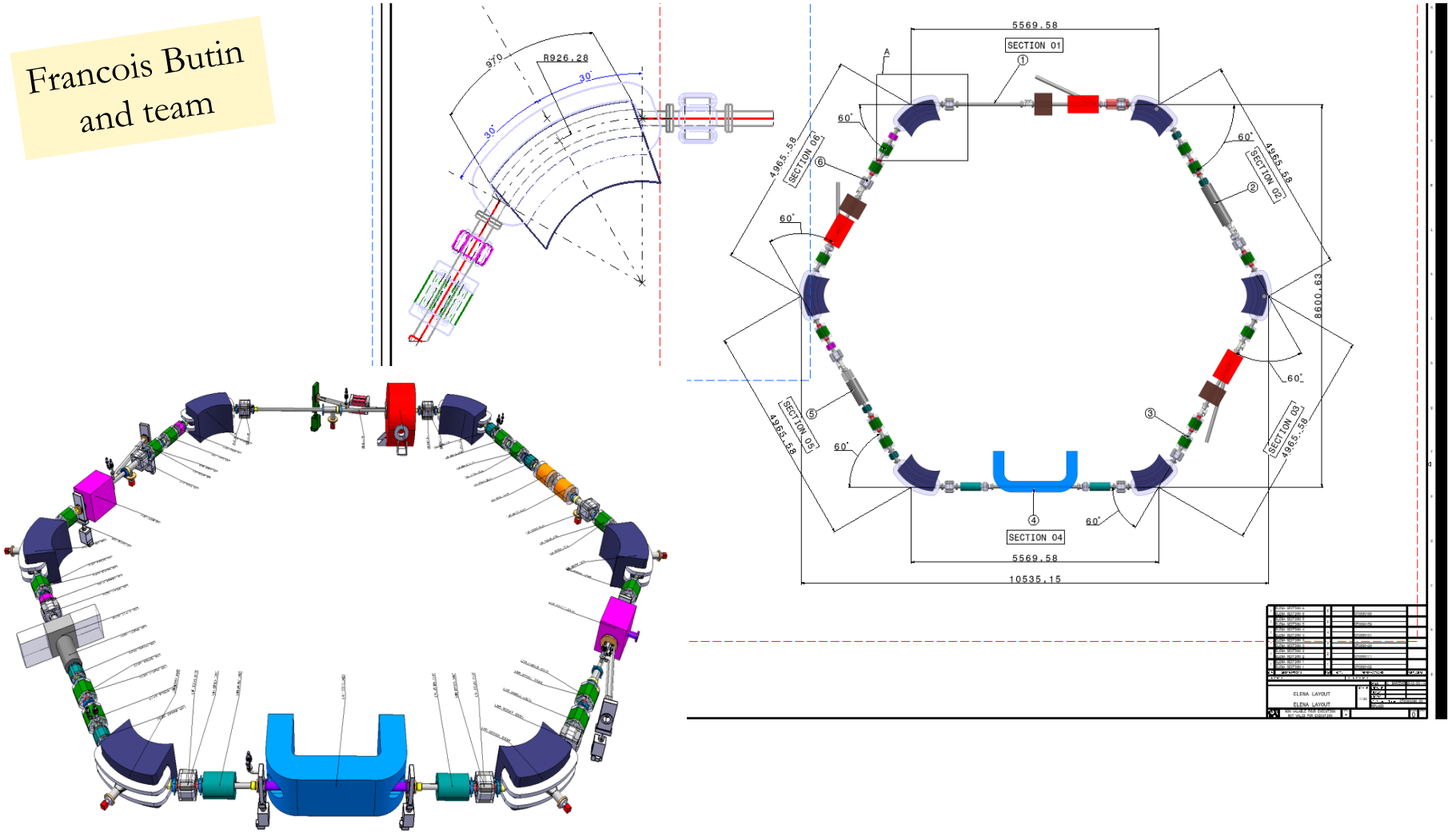
1	TRANSFER LINES (YTZ) / LIGNES TRANSFERT (YTZ)	2
1	ELENA RING LAYOUT / LAYOUT ANNEAU ELENA	1

Lattice and Layout

Francois Butin and team

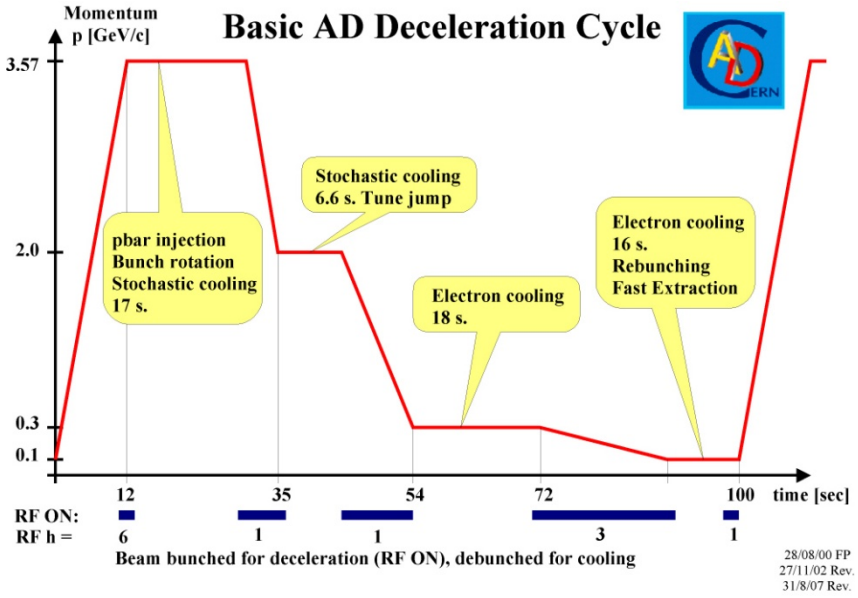


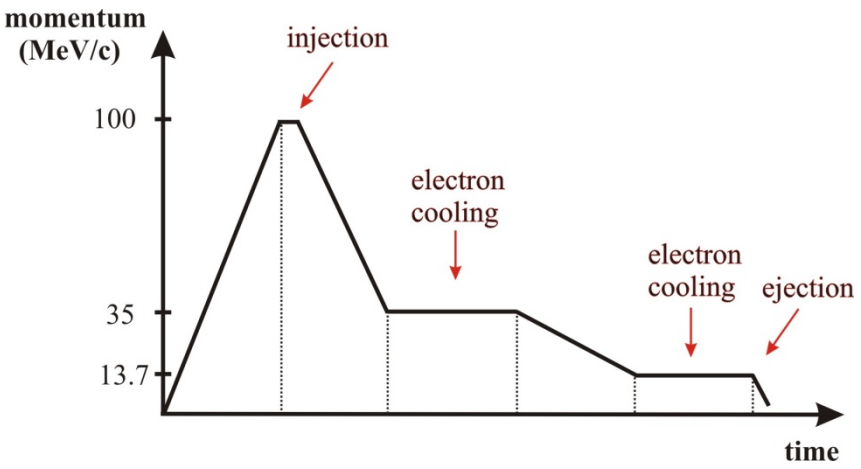
Integration and mechanical design started

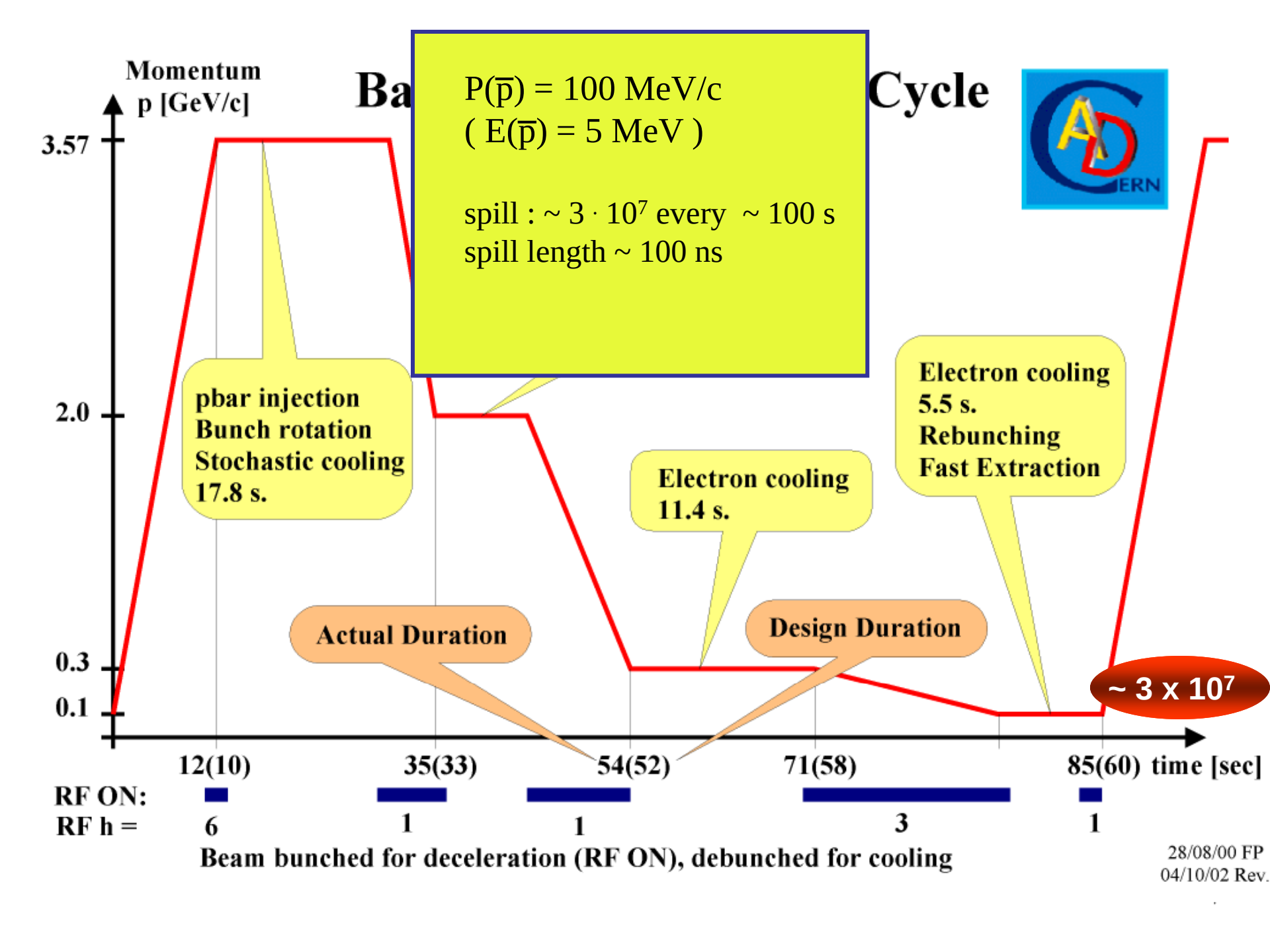
Repetition rate

AD cycle is about 100 sec now

ELENA cycle is expected about 25 sec, well fitting in AD cycle






Momentum
p [GeV/c]
Ba
Cycle
P(p̄) = 100 MeV/c
(E(p̄) = 5 MeV)
spill : ~ 3 · 10^7 every ~ 100 s
spill length ~ 100 ns
3.57
2.0
0.3
0.1
pbar injection
Bunch rotation
Stochastic cooling
17.8 s.
Electron cooling
11.4 s.
Electron cooling
5.5 s.
Rebunching
Fast Extraction
Actual Duration
Design Duration
~ 3 x 10^7
12(10)
35(33)
54(52)
71(58)
85(60)
time [sec]
RF ON:
RF h =
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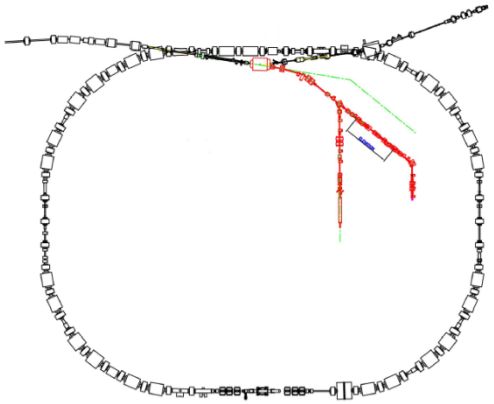
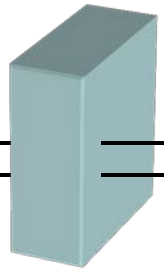
1
3
1
Beam bunched for deceleration (RF ON), debunched for cooling
28/08/00 FP
04/10/02 Rev.



5.3 MeV antiprotons/ ~ 100 sec

~ 3 x 10^7



~4 keV antiprotons/ ~ 100 sec

~ 1 x 10^5

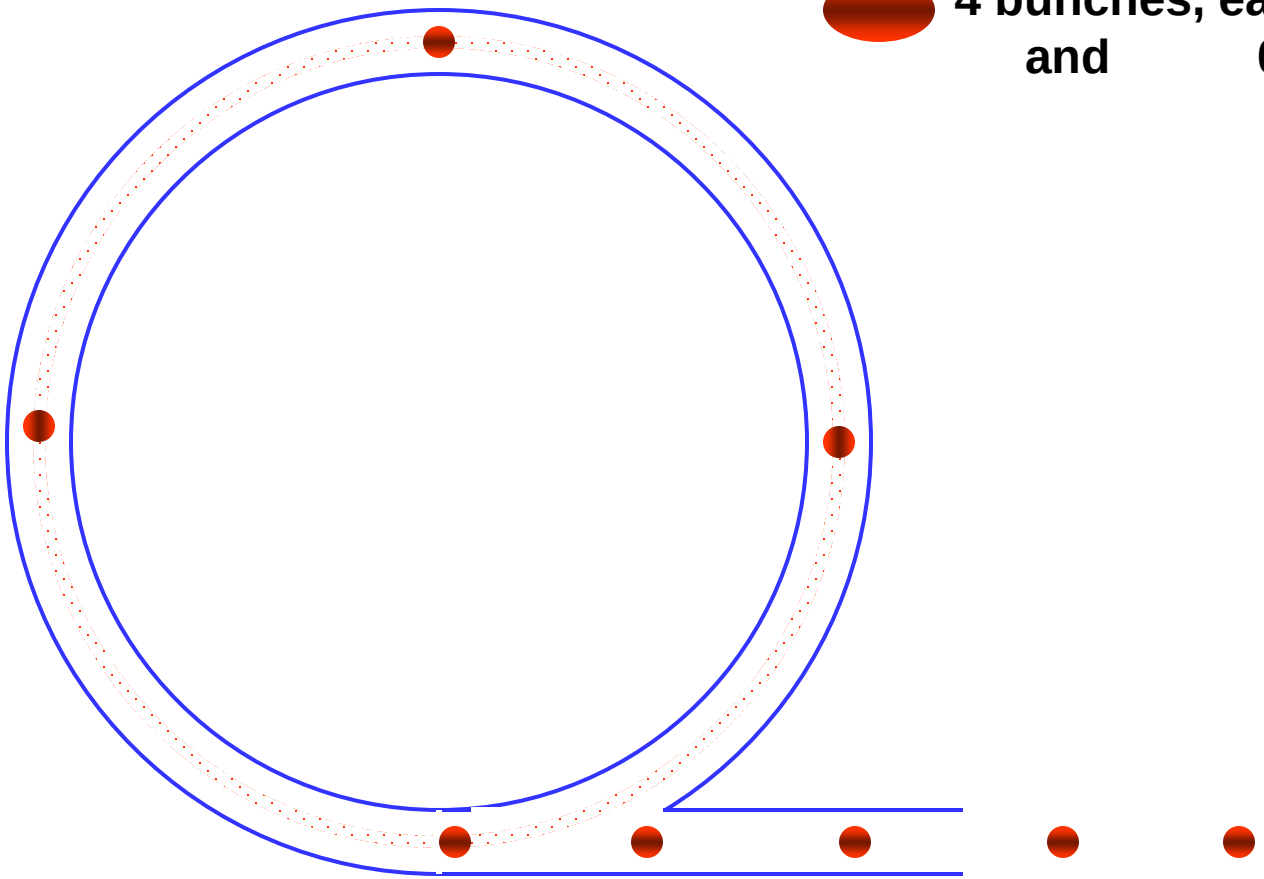
ATRAP`s very best value: 1.3x10^5

2.99 x 10^7 antiprotons lost

→ efficiency 3 x 10^{-3}

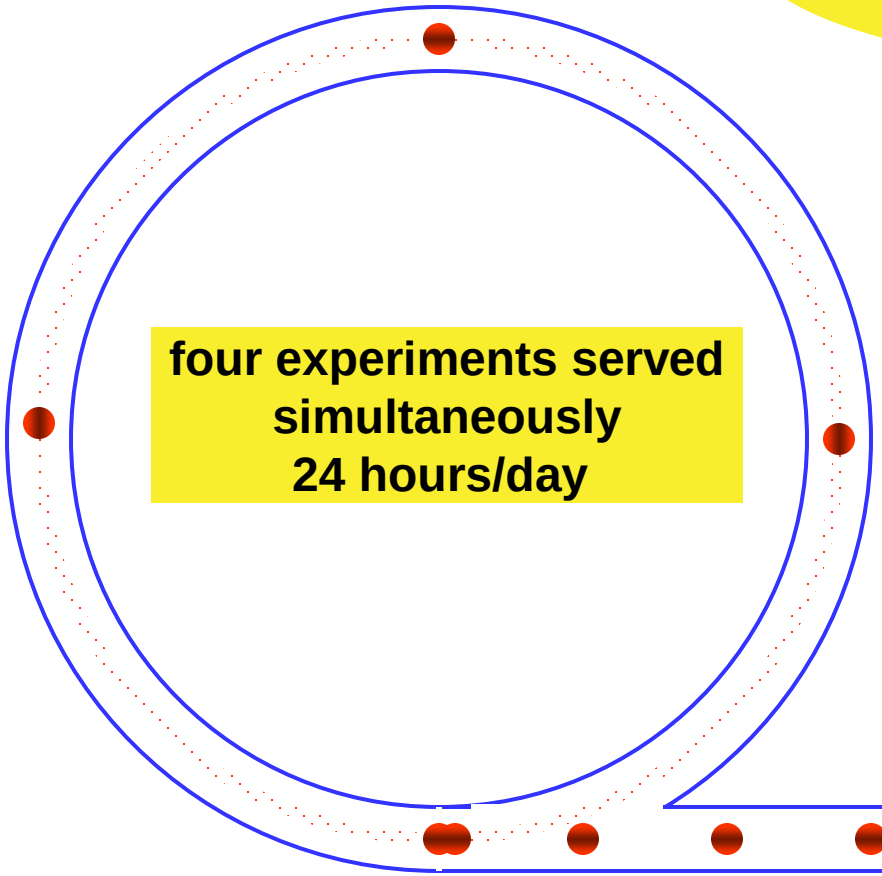
coasting beam: 1.8 x 10^7 $\bar{p}$´s

4 bunches, each: 1.3 m / 300 ns:
and 0.450 x 10^7 $\bar{p}$´s

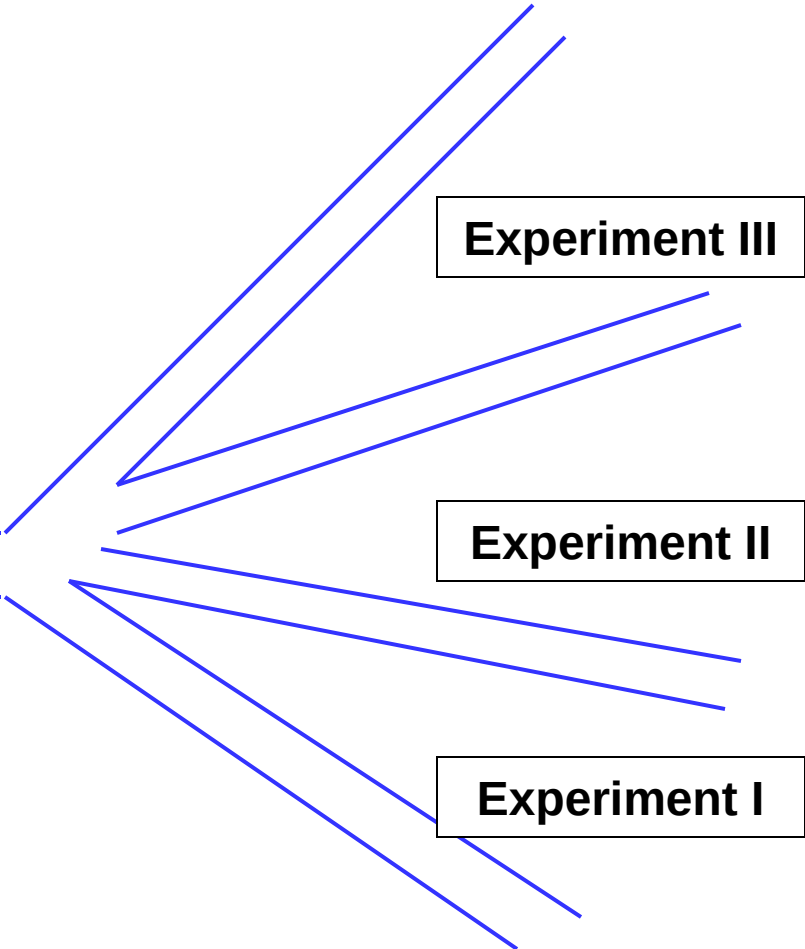


1.8 x 10^7 $\bar{p}$´s to one experiment

0.450 x 10^7 $\bar{p}$´s
to four different experiments



four experiments served simultaneously 24 hours/day



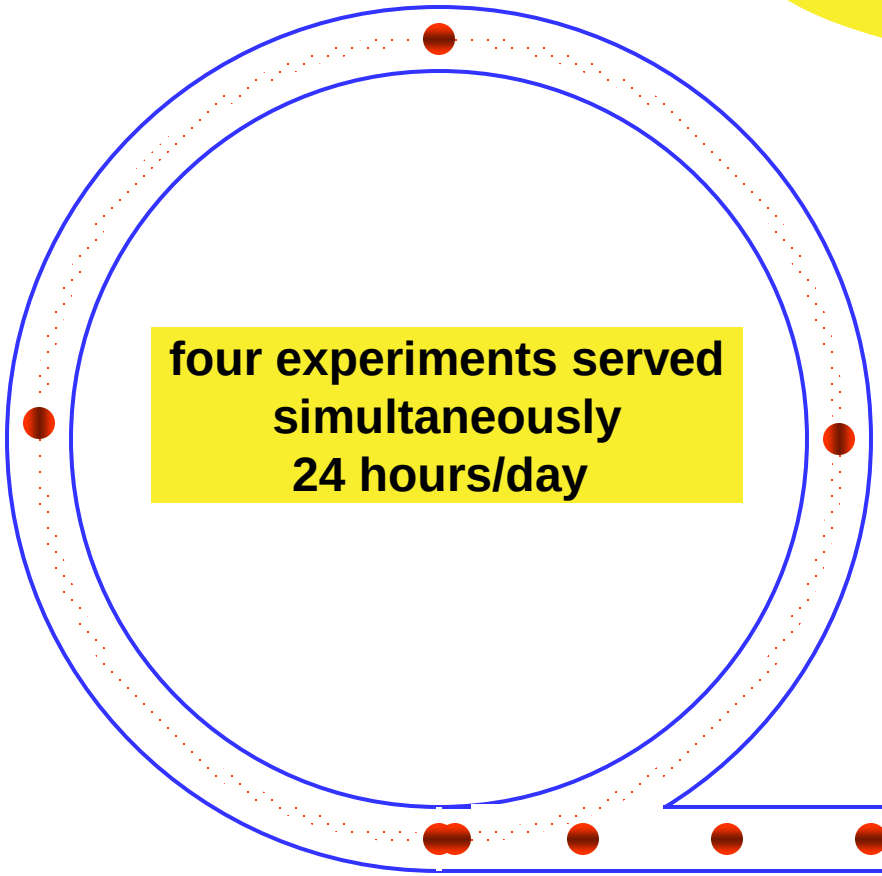
Experiment IV

Experiment III

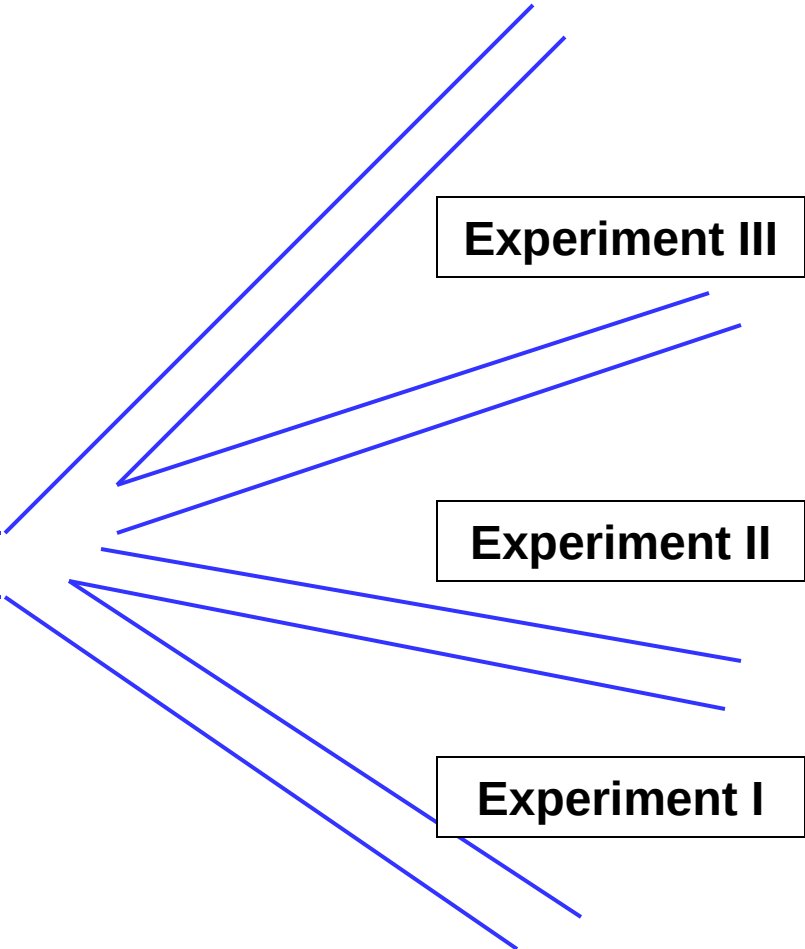
Experiment II

Experiment I

0.450 x 10^7 $\bar{p}$´s
to four different experiments



four experiments served simultaneously 24 hours/day



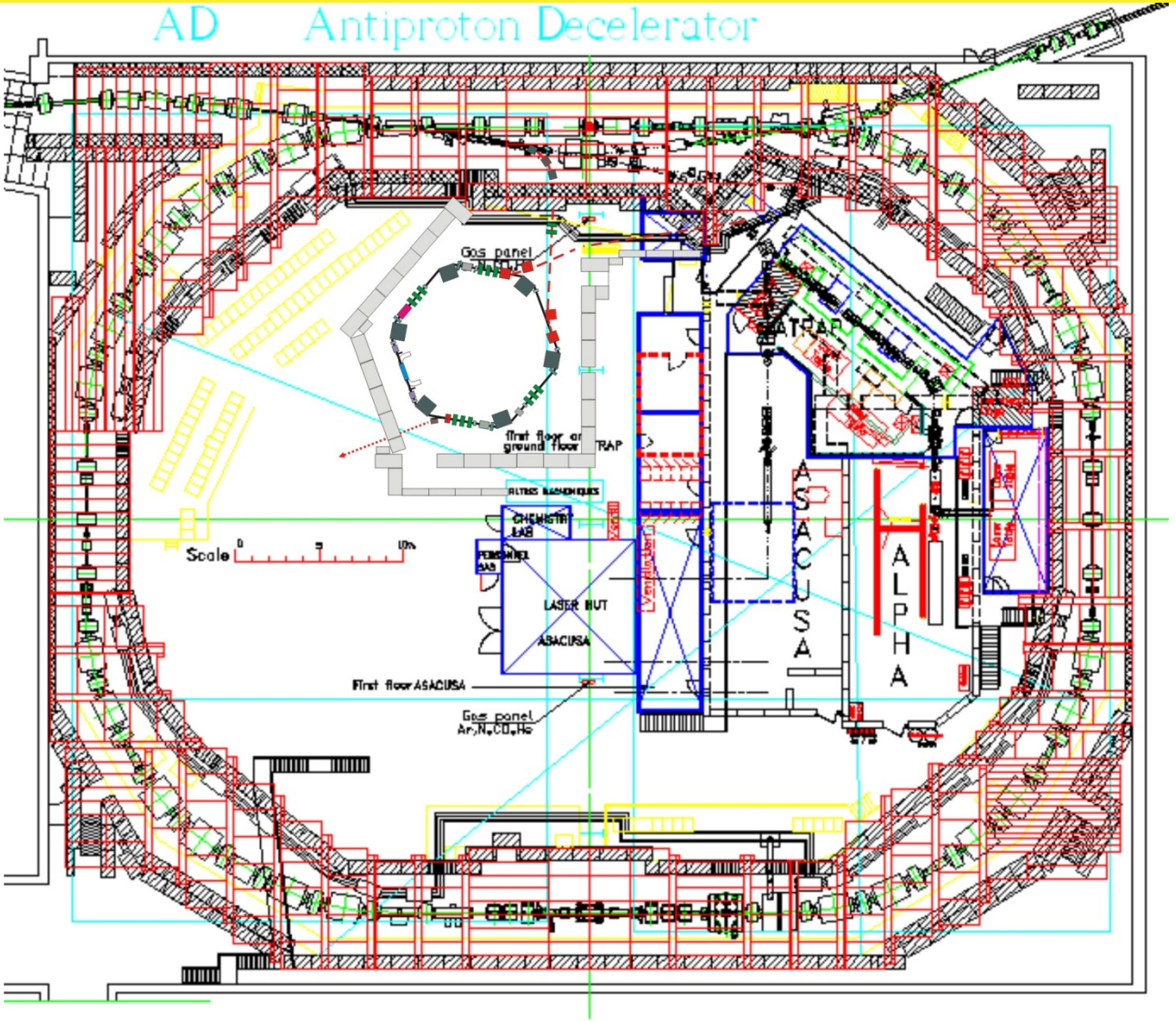
Experiment IV

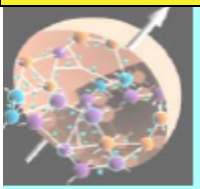
Experiment III

Experiment II

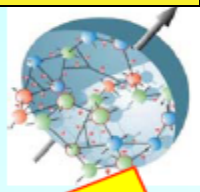
Experiment I

There is a clear consensus among the AD experiments
that further large improvements
can only be achieved using a cooled antiproton beam from ELENA



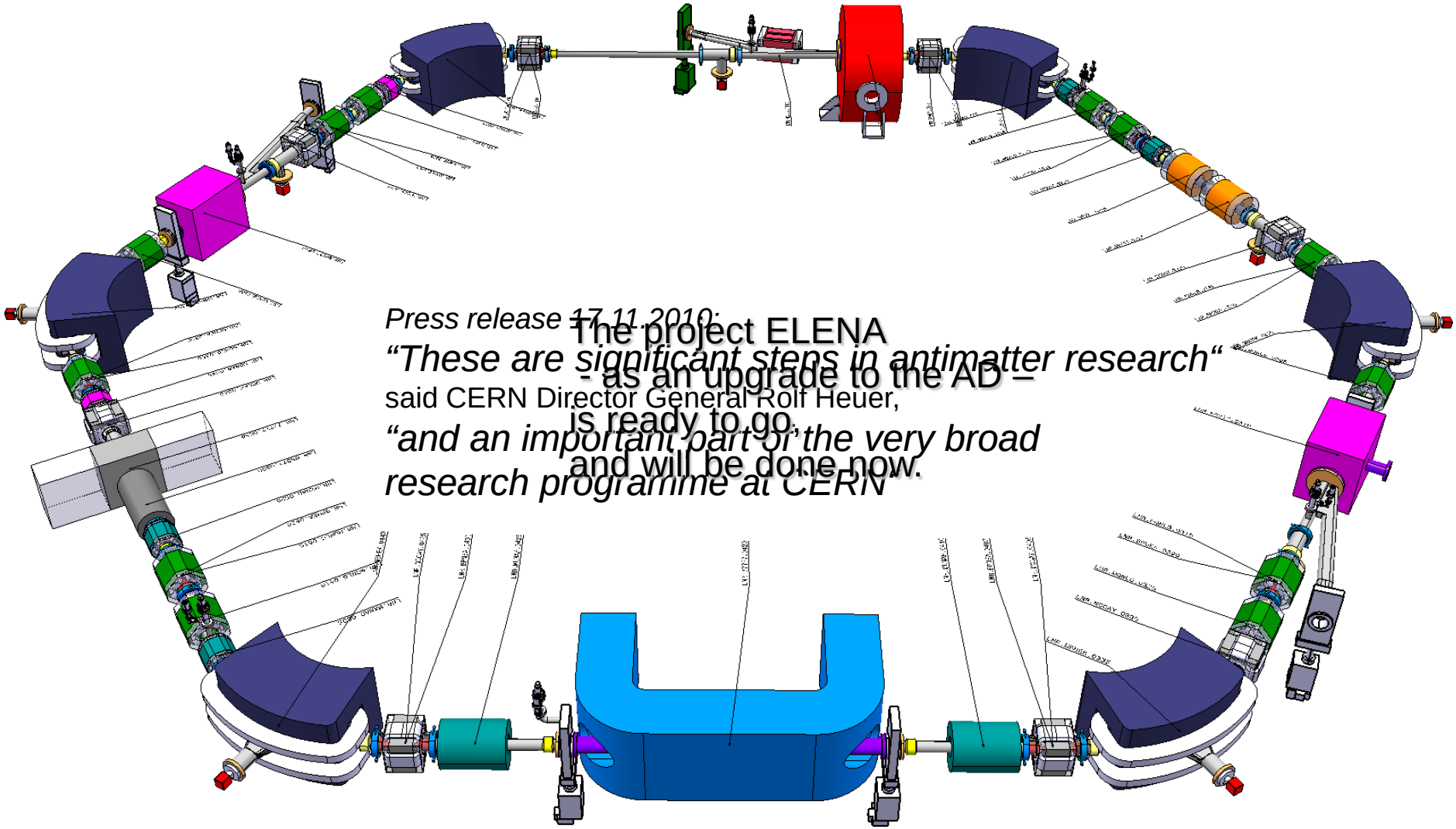


Summary and Conclusions



- **Highly Motivated Urgent Antiproton Experim**
  with robust Discovery Potential and Hi
  CPT, Gravity, Determination of Fundamental
  SM Physics, Applications (Therapy)
- **Unique Facility world**
- **Creative and** **g Community**
  Young
  echnology
- **good on Time Path**
- **Program needs more particles**
  → **ELENA** well motivated
- **Productive and Prosperous Future Ahead**

Low Energy Antiproton contributions to Physics just started
Precision takes Time Care and Particles



The project ELENA
- as an upgrade to the AD –
is ready to go,
and will be done now.

Press release 17.11.2010:
"These are significant steps in antimatter research"
said CERN Director General Rolf Heuer,
"and an important part of the very broad research programme at CERN"

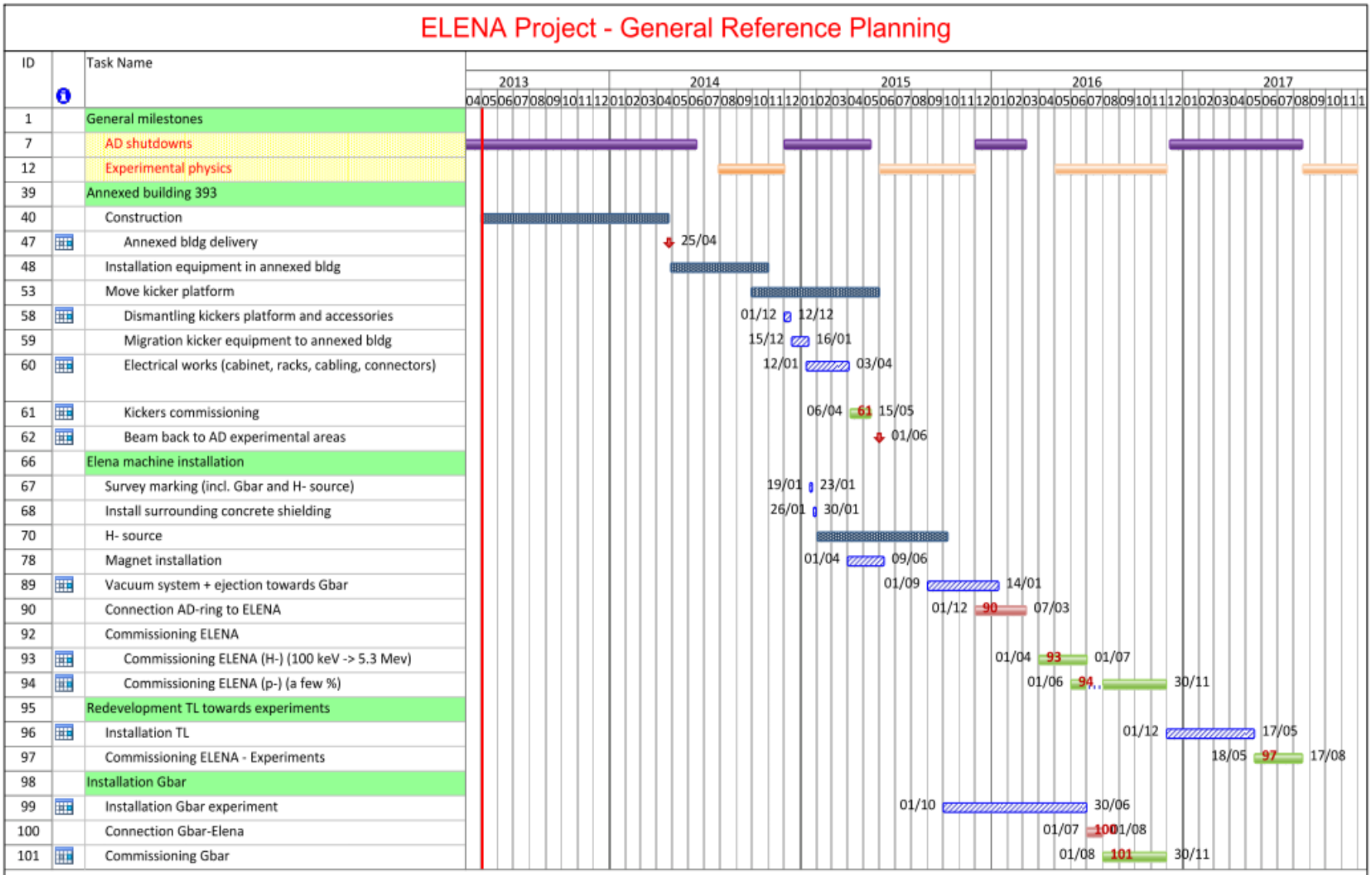
Planning

- TDR(first draft) June 2013
- New building construction 05/2013 – 04/2014
- Infrastructure installation 05/2014 – 12/2014
- Kicker generator relocation 12/2014 – 05/2015
- ELENA installation (w. AD Physics) 05/2015 – 05/2016
- ELENA commissioning (w. AD physics) 06/2016 – 12/2016
- Ejection line replacement 01/2017 – 06/2017
- Commissioning (w. physics) 06/2017 – 12/2017

$\Rightarrow$ 2 short years of AD physics:

  - 2014: late start after LS1 ~ July/August
  - 2015: late start after kicker installation ~ June

ELENA Project - General Reference Planning



Status of external Contributions

- **Univ. Tokyo and MPQ-MPI**: (MoU signed)
  - 2 MCHF (possibly electron cooler)
  - 7 FTE (identified, electrostatic transfer lines and devices)
- **Cockcroft Institute & Univ's and Swansea University :**(MoU signed)
  - Costing of the order of 500 kGBP has been applied by U Liverpool,
  - A proposal has been submitted for work : this would cover 2 Postdocs, some PhD students and equipment; the overall funding requested is about 1 M€; a decision is expected until June.
- **Denmark:** (MoU signed)
  - Applied successfully for the money for bends and quadrupoles, possibly funding for a postdoc
- **IKP-FZ Julich**
  - Work has started and will be again discussed tomorrow afternoon: substantial development work is required to make such a source operational for ELENA commissioning. Many interfaces to be clarified (vacuum with differential pumping, design of lines, integration, infrastructure …).
- **Univ. Brescia:** 50 kEuros (MoU signed)
- **RIKEN (new since last ADUC)** (MoU signed)
  - Compensation solenoids for electron cooler
  - Manpower (student)
- **TRIUMF:** Help for design of electrostatic transfer lines (MoU signed)
- **Hemholtz Institute Mainz:** Construction of supports
- **Manne-Siegmann:** Help with ELENA commissioning
- **Berkeley:** DOE does not (yet) support – MoU not signed, but discussion not yet abandoned!
- **CEA-IRFU Saclay-SIGMAPHI:** only prototypes are interesting for them – did not sign MoU, but still discussions

Conclusion

- **With the ELENA Project,**
  antiproton physics will continue for the next ~ 20 years and
  opens the door to a new physics era.

- **To ensure a long life to ELENA physics**
  all upstream machines will be consolidated (AD, TA, PS).

- **The new multipurpose building gives space for**
  ELENA machine and for new antiproton experiments in the future (construction started)

- **… the community is happy waiting for physics with antiprotons from ELENA ……. in 2017 !**

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EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
LABORATOIRE EUROPÉEN POUR LA PHYSIQUE DES PARTICULES
EUROPÉEN LABORATORY FOR PARTICLE PHYSICS

Programme

A/To: Professor Dr. Rolf Heuer
De/From: Christian Carli, Stephan Maury and Walter Oelert
Copie/Copy: S. Myers, S. Bertolucci, J. Gillies, M. Brice
Concerne/Subject: ELENA Ground-Breaking Ceremony, 17 of June 2013

ELENA Ground-Breaking Ceremony 17 June, 2013

Timing

Building 393(North entrance of the 193 building, 854 or 93)

11:00 – 11:10 Arrivals of guests on site
11:10 Welcome address – Christian Carli, Stephan Maury
11:15 Rolf Heuer, CERN Director-General starts digging with a mini-shovel. Photograph.
11:20 Christian Carli and Stephan Maury, ELENA Project Leaders start digging with a mini-shovel. Photograph.
11:25 The DG unveils the official commemorative plaque:

**”This plaque was unveiled on 17 June, 2013
by Prof. Dr. Rolf Heuer, Director General of CERN,
to commemorate the ground breaking for the extension of the Antiproton Hall
for the construction of the ELENA (Extra Low ENergy Antiproton) Ring.”**

11:35 Speech - Walter Oelert
11:40 Photograph with R. Heuer, ELENA core.

11:50 Family photograph.
12:00 Christian Carli and Stephan Maury invite the guests for an aperitif

ELENA

Extra Low ENergy Antiprotons