Status of the ELENA transfer lines

with special consideration of vacuum, hand-over optics and beam time distribution after 2017

W. Bartmann, D. Barna, J. Borburgh, R. Kersevan,
S. Pasinelli, J.-F. Poncet, G. Vanbavinckhove

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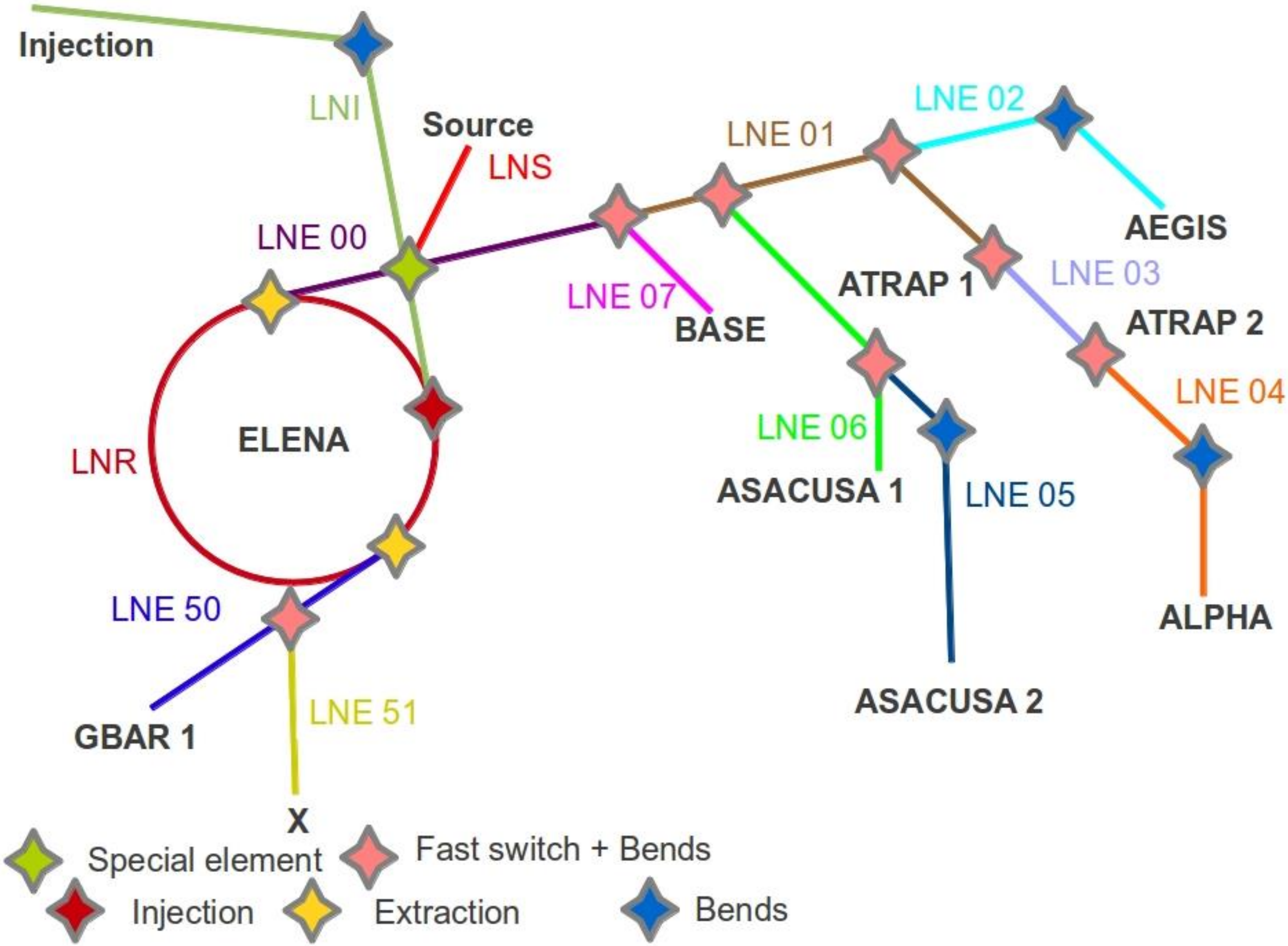
Outline

- Optics
  - Beam envelope vs Good Field Region of HW
  - Optics for one line as example
- Status of the hardware
- Vacuum
- Beam distribution possibilities
- Schedule


Injection
LNI
Source
LNS
LNE 00
LNE 01
LNE 02
AEGIS
LNE 07
BASE
ATRAP 1
LNE 03
ATRAP 2
LNE 04
LNE 06
LNE 05
ASACUSA 1
ASACUSA 2
ALPHA
LNR
ELENA
LNE 50
GBAR 1
LNE 51
X
Special element
Fast switch + Bends
Injection
Extraction
Bends

Handover parameters

Aperture definition

- Beam envelope:

$$\Sigma_{x,y}(95\ \%) = \sqrt{\beta_{x,y} \cdot \kappa_{x,y} \cdot \epsilon_{x,y}\ (95\%)} + D_{x,y} \cdot \kappa_{x,y} \cdot \frac{\delta p}{p}(95\%)$$

$$\kappa_{x,y} = 1.2$$

- Good field region (diameter):

$$GFR = \Sigma_{x,y} + TR_{x,y}\sqrt{\frac{\beta_{x,y}}{\beta_{max}}} + error_{align}$$

Max 10 mm

4 mm

$$GFR_{spec} < 40\ mm$$

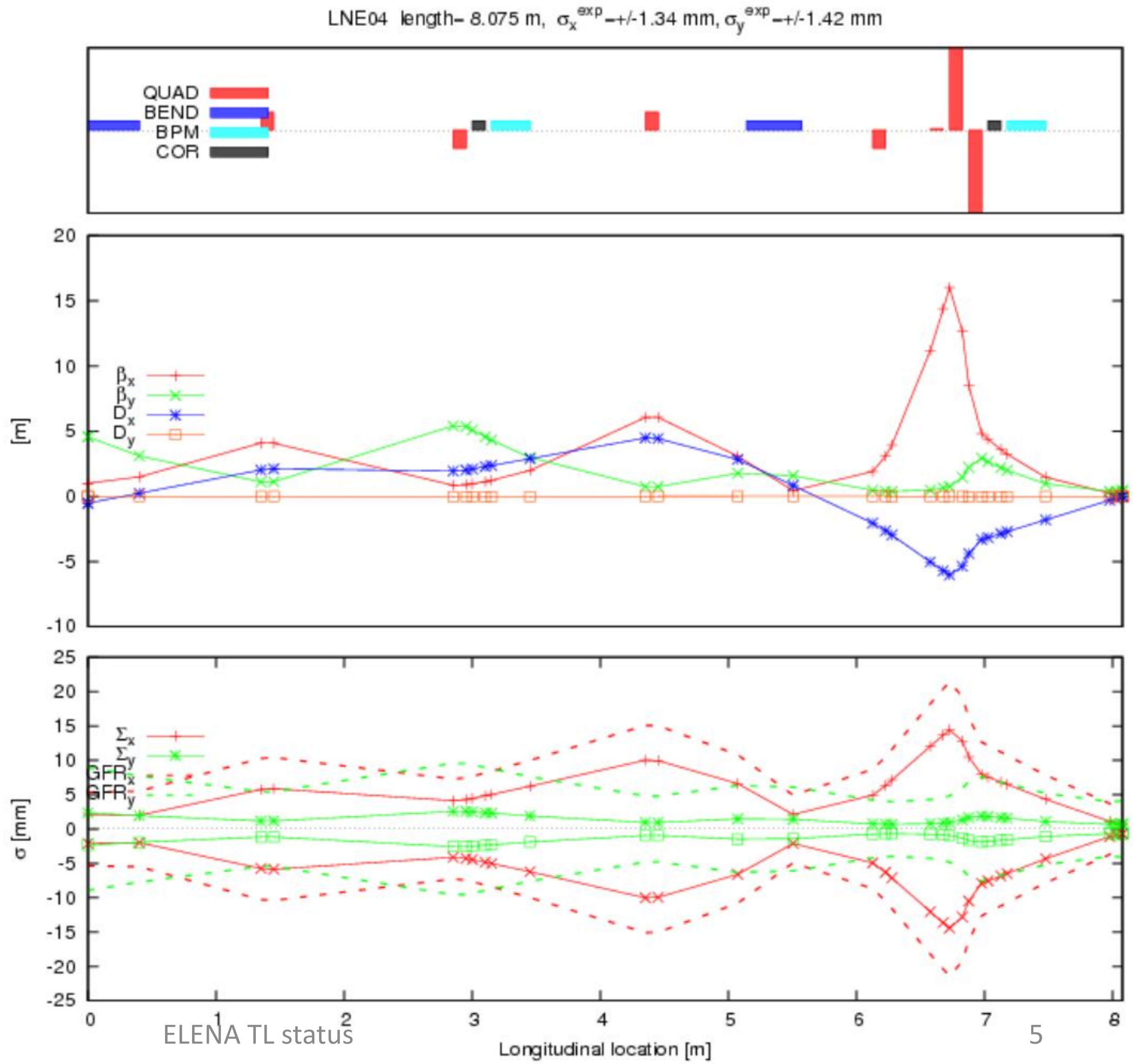
- Beam envelope at experiments:

$$\Sigma_{x,y}(95\%) = 1 - 2\ mm$$

LNE04 – last part of ALPHA line

Line elements are set, a few details to finalize:

- Some quadrupoles seem reducable but help for operational adjustments of the beam size
- Place monitors in areas of low dispersion to measure clean profiles
- Complete error studies



Handover parameters

list of beam-sizes at the experiments

Experiment	$\Sigma_x(95\ \%)$ [mm]	$\Sigma_y(95\ \%)$ [mm]
BASE	2.0	1.7
ASACUSA1	1.9	1.0
ASACUSA2	2.0	2.0
ATRAP1	1.2	0.7
ATRAP2	1.9	1.2
ALPHA	1.3	1.4
AEGIS	1.9	1.1
GBAR	1.0	1.0

Handover parameters

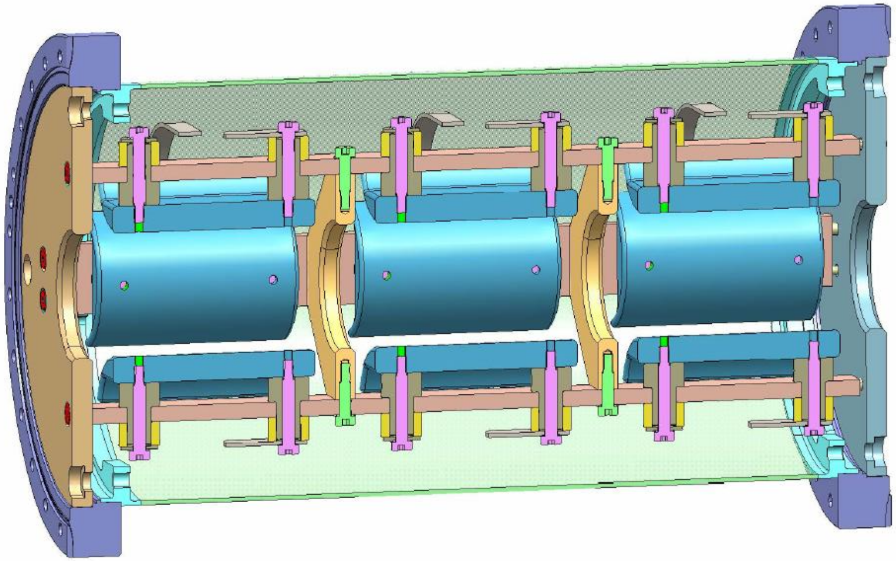
Information available online

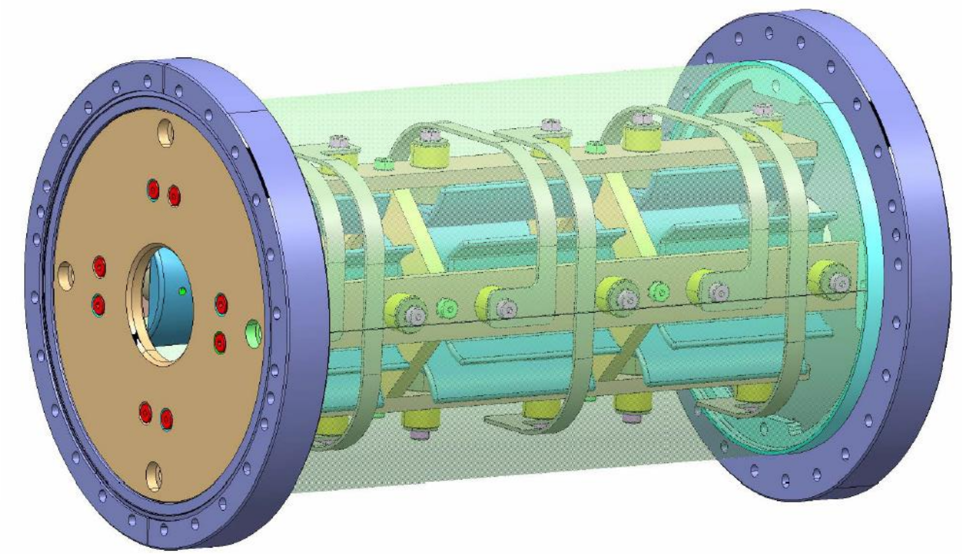
- For detailed and up-to-date parameters at handover points per experiment:

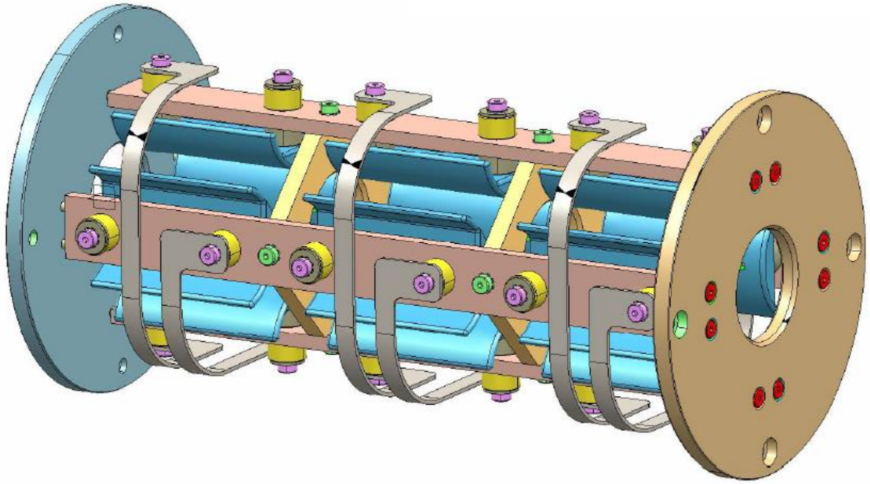
http://project-elena-optics.web.cern.ch/

  - 6x6 sigma matrix
  - Beam size
  - Optics functions (β,α, D,…)
  - Hand over locations

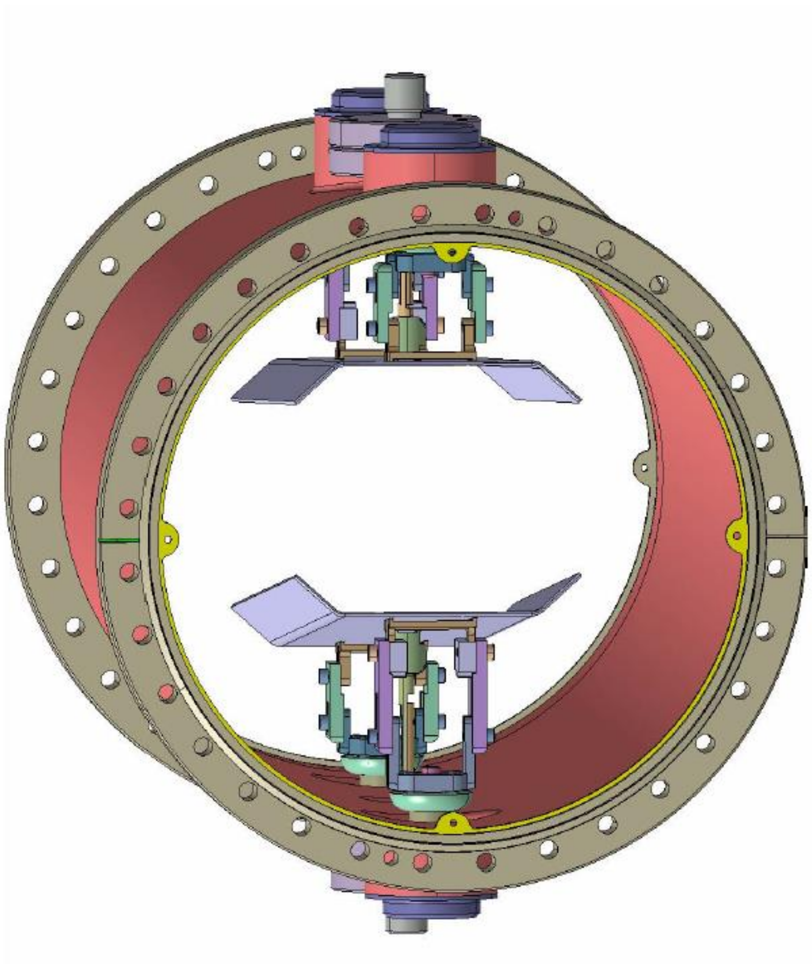
Electrostatic HW - Quadrupoles

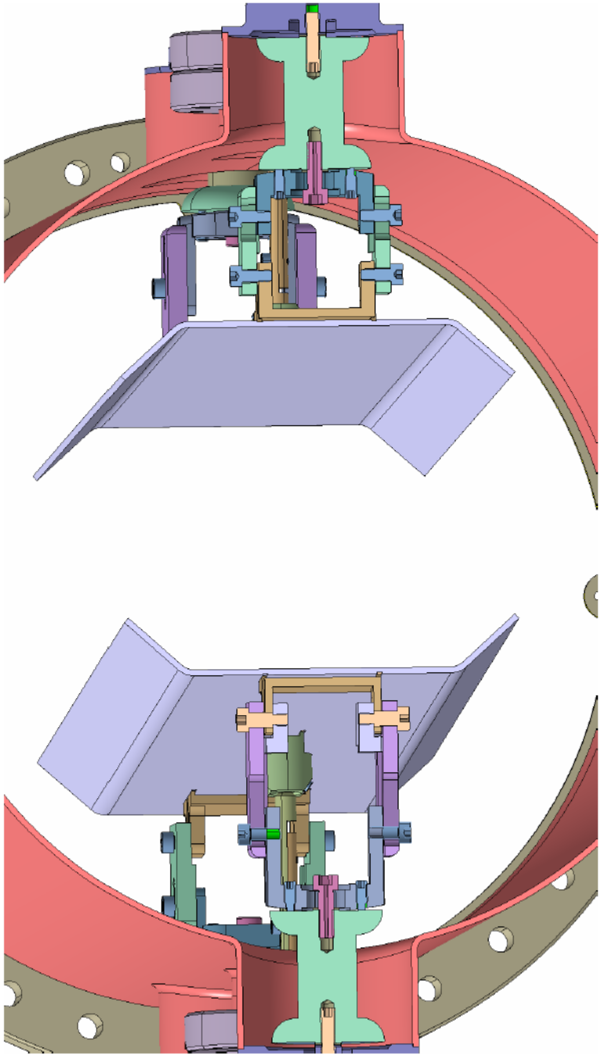




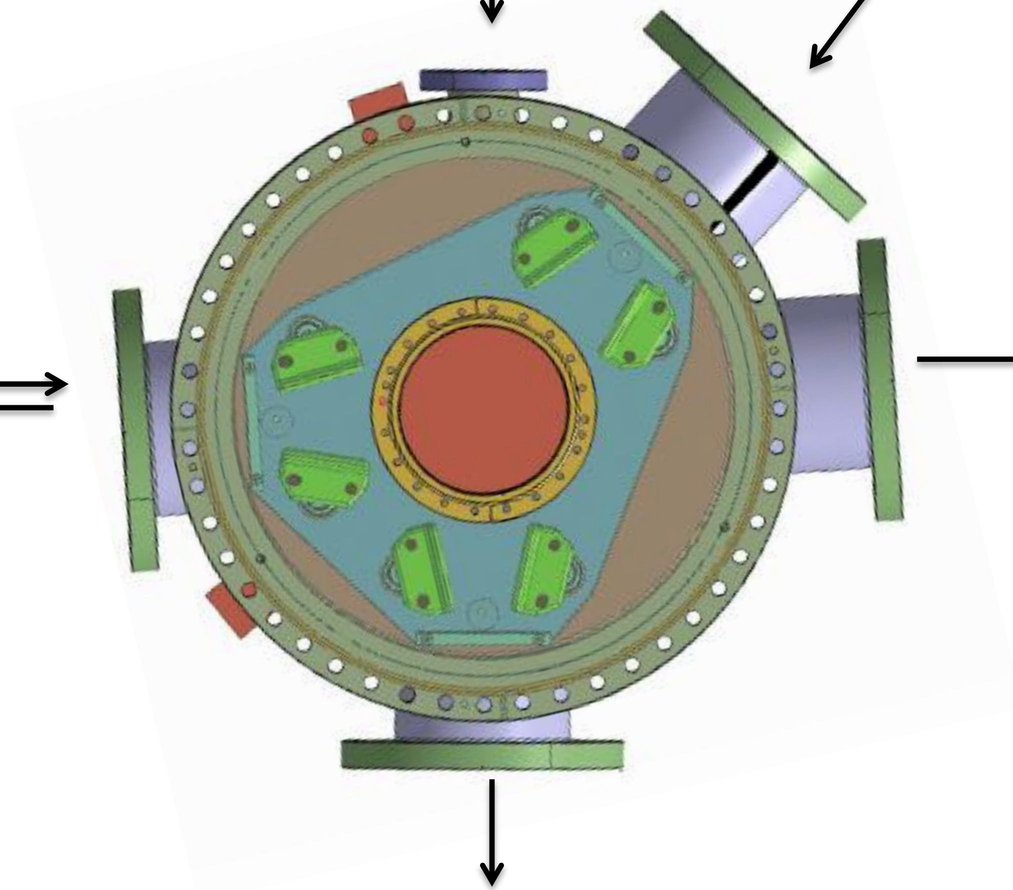


Electrostatic HW – Fast Deflector

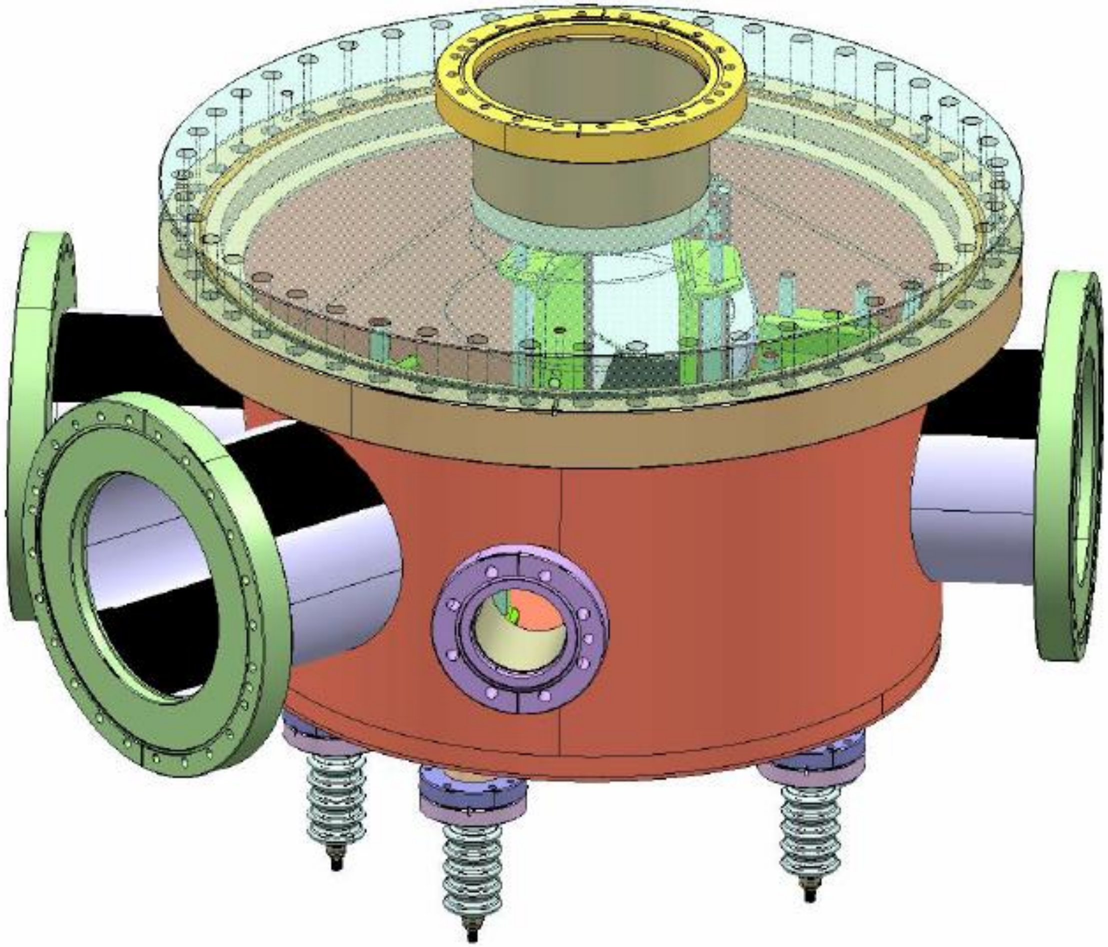




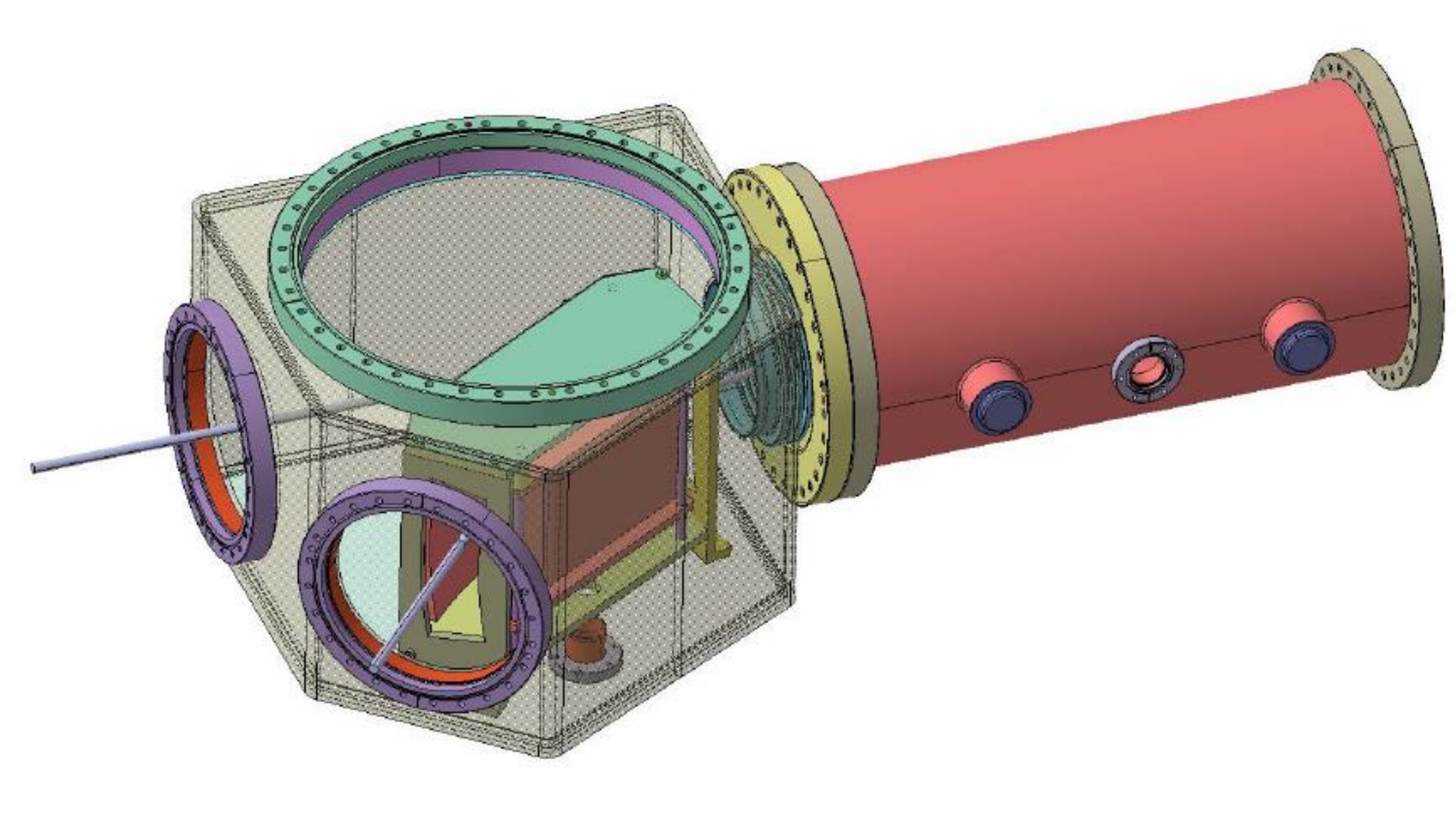
Electrostatic HW – Ion Switch



Electrostatic HW – Ion Switch



Electrostatic HW – Fast Deflector + Bend



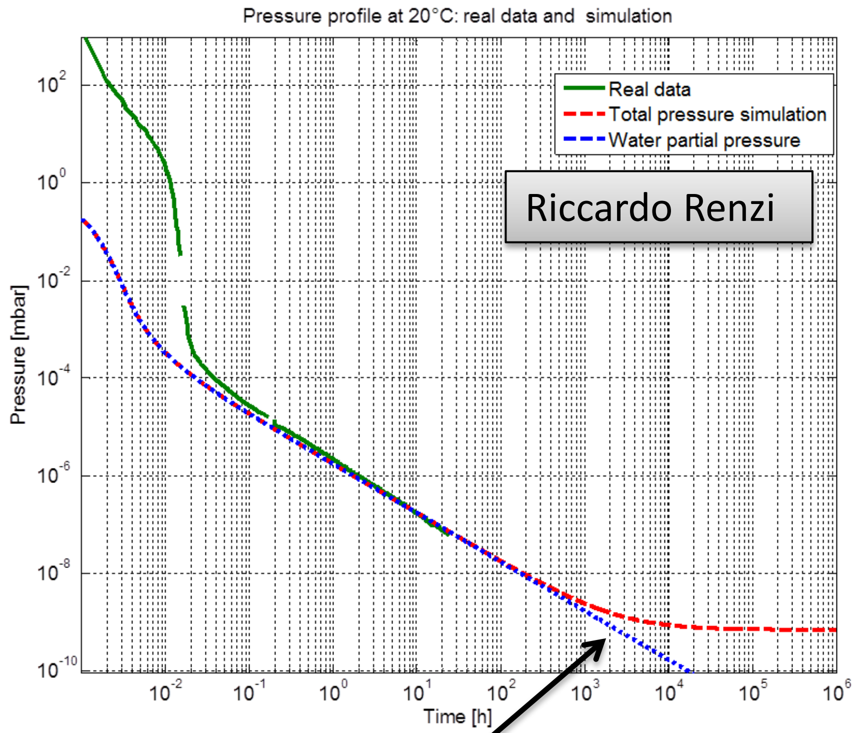
Test system vacuum - simulation and measurements

Riccardo Renzi, TE-VSC-IVM, Jan 2014

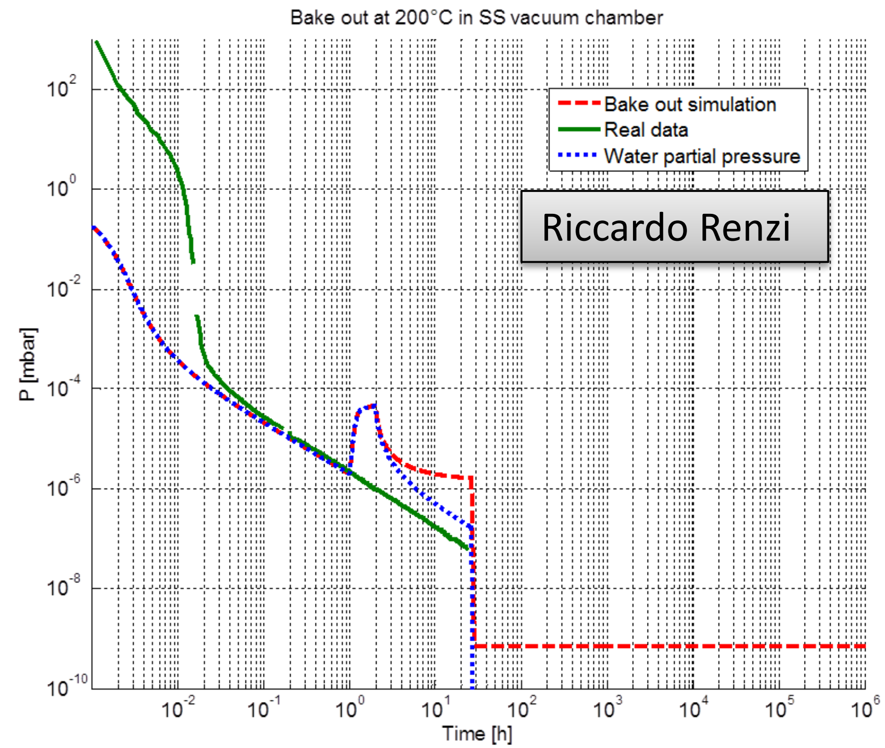
- System’s geometry:
  - 3m-long DN100 stainless steel tube connected to a small dome housing the pressure gauges and other devices (valves)
- The pressure is measured via 3 different gauges
- Surface of 13,000 cm^2 and volume of 35 liters
- The specific outgassing rate is derived to be 6.5e-12 mbar*l/s/cm^2 (2x higher than usually assumed but this is what fits the data)

Test system vacuum – pump down curves

Without bake-out



With bake-out



several weeks to recover after a full venting

- 24 h bake-out cycle to reach 1e-9 mbar
- With NEG 1e-11 mbar in the same time

TL vacuum – pressure/pump time

- Vacuum pressure
  - Need ~1e-9 mbar for the beam
  - Close to the machine differential pumping

…this can be reached without NEG and bake-out if recovery time is of low importance!

- Pump-down time to reach 1e-9 mbar water pressure
  - Neither NEG nor bake-out: several weeks
  - Only bake-out: 24 h (50 kCHF)
  - Fully bakeable NEG coated lines: would reach in a 24 h bake-out cycle 1e-11 mbar or less (100 kCHF)

… strong dependence on the vacuum sectorisation

TL vacuum - sectorization

- Vacuum sectorization
  - More valves reduce the recovery time but ~ 10 kCHF per valve
  - Present assumption:
    - Each fast switch + bend unit is equipped with 3 valves → each experimental zone has its own vacuum sector to avoid cross talk
    - Valves at handover between line and experiment
    - Gives ~ 30 valves corresponding to 300 kCHF
    - Put additional valves in long sections if needed

- Probability of unplanned intervention with breaking the vacuum: less than once a year

Beam time distribution

- What changes from machine side with ELENA
  - Nominal scenario: 4 bunches in the machine
  - Fast deflector gives possibility to extract a single bunch out of the train while leaving the others in the machine → can split the same train between the two extractions
  - Also the full train can be extracted and separated into the different experiments' channels by fast deflectors in the lines

- Considering 6 users every 3 cycles an equal number of bunches can be distributed

User	Cycle 1	Cycle 2	Cycle 3
BASE	x	x	
ASACUSA	x	x	
ATRAP	x		x
ALPHA	x		x
AEGIS		x	x
GBAR		x	x

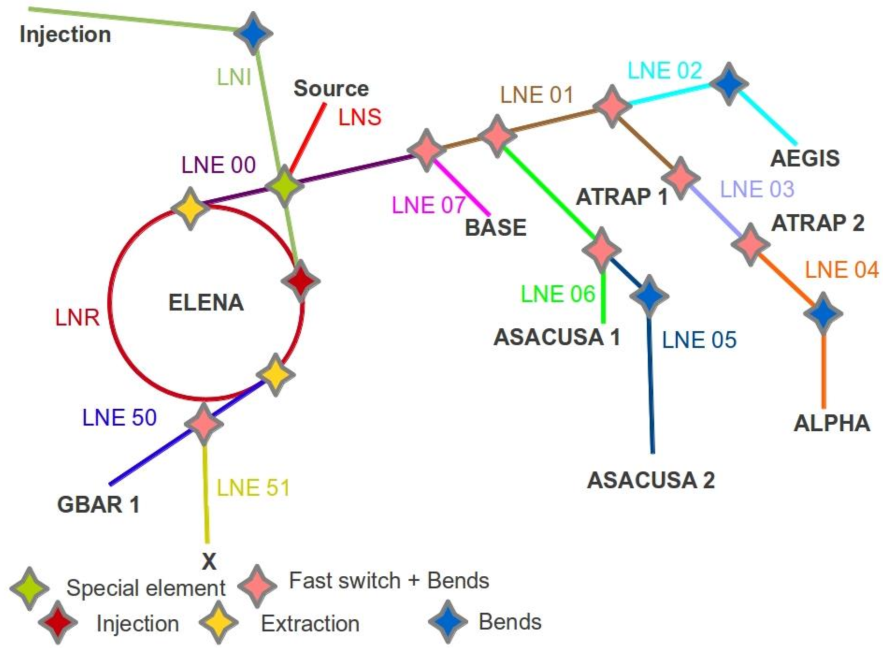
Beam time distribution

- Redistribution in case not all experiments require beam
  - If beam is required a request has to be set via control system
  - Manual control of beam destination in the beginning
  - Automatic re-distribution depending on number of users and bunches for later stage
  - Synchronisation signal to ensure correct timing is sent at beginning of cycle
    - Details of communication between controls/experiments to be clarified

- Could envisage H- beam in ELENA and TLs within the AD supercycle (setup of trajectory, transmission, timing,…)
  - Flexibility from machine and controls is given

- Security measure for experimental zone access while others take beam
  - Beam stoppers or interlock on bends
  - In case of interlock, e.g. push access door, the beam is dumped within the machine or LNI

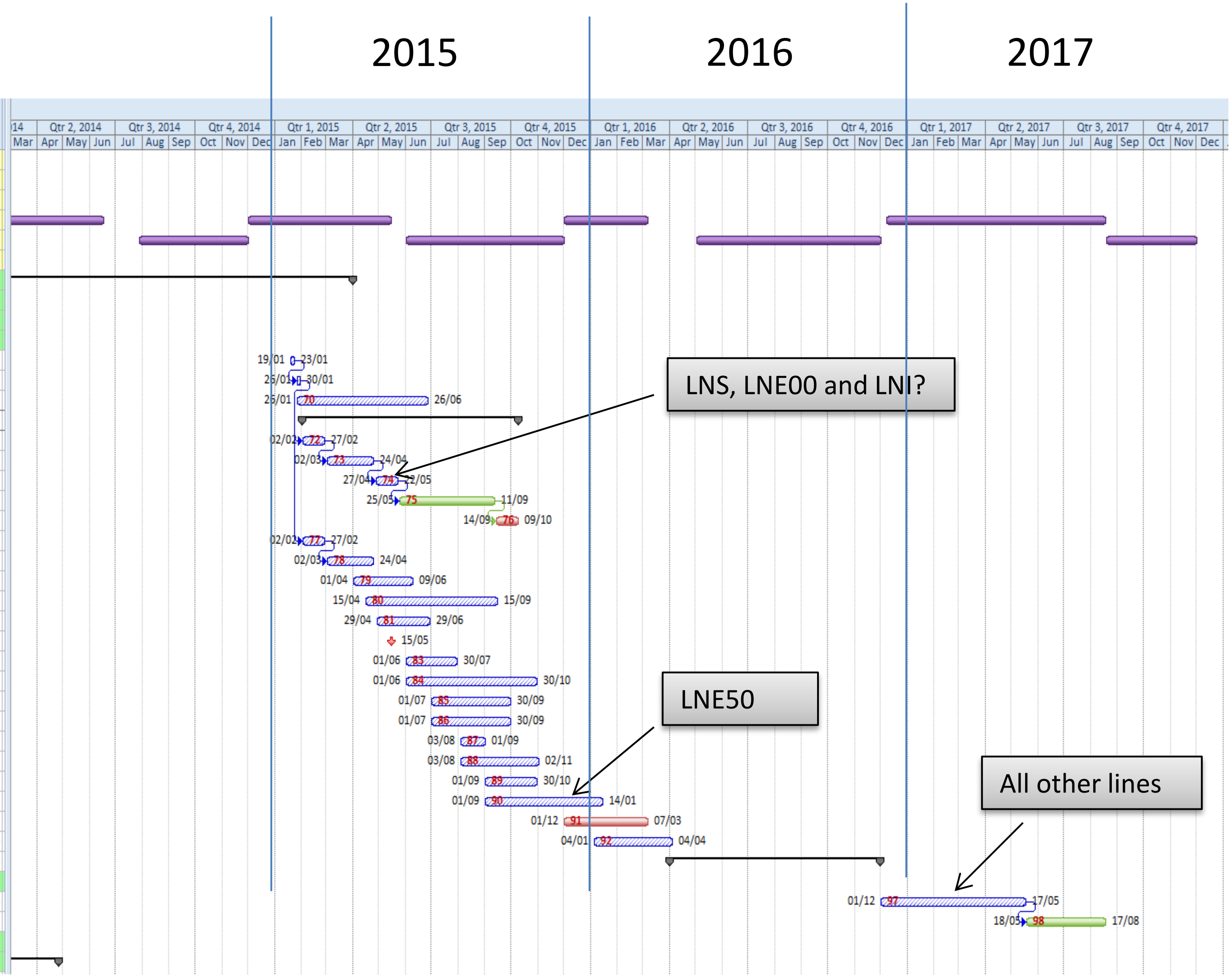
Official planning – Installation dates by line



Line	Installation start	includes
LNI	04/2015	Magnetic + electrostatic quadrupoles
LNS	**04/2015 ?**	**Ion switch, matching unit**
LNE00	**09/2015**	**Fast deflector, matching unit**
LNE50	**09/2015**	**Fast deflector, matching unit**
All other lines	12/2016	Fast deflector, matching unit, quadrupole unit, bend unit

Official planning

	Task Name	Duration	Start
4	General layout hall 193 and annexed bldg	0 days	Mon 03/09/12
5	TDR Elena project	0 days	Mon 15/10/12
6	TDR Gbar project	0 days	Fri 14/12/12
7	+ AD shutdowns	1169 days?	Mon 17/12/12
12	+ Experimental physics	845 days	Mon 28/07/14
17	+ Finance Committee meetings 2013	0 days	Wed 13/03/13
19	+ Studies & purchasing activities	709 days?	Thu 31/05/12
39	+ Annexed building 393		Wed 01/02/12
64	+ Redevelopment Hall 193		
67	− Elena machine installation		
68	Survey marking (incl. Gbar and H- source)	5 days	Mon 19/01/15
69	Install surrounding concrete shielding	5 days	Mon 26/01/15
70	Equip control racks	5 mons	Mon 26/01/15
71	− H- source	180 days	Mon 02/02/15
72	Installation source	20 days	Mon 02/02/15
73	Cabling and Control	40 days	Mon 02/03/15
74	Add vacuum / test line	20 days	Mon 27/04/15
75	Commissioning source	80 days	Mon 25/05/15
76	Connection to ELENA machine	20 days	Mon 14/09/15
77	Cable trays / lightning / AC cabling	20 days	Mon 02/02/15
78	Install cooling network	40 days	Mon 02/03/15
79	Magnet installation	50 days	Wed 01/04/15
80	Cable-laying campaign	5 mons	Wed 15/04/15
81	Install kickers	2 mons	Wed 29/04/15
82	AD closing / restart	0 days	Fri 15/05/15
83	Install septa	2 mons	Mon 01/06/15
84	Install power converters	5 mons	Mon 01/06/15
85	Install RF	3 mons	Wed 01/07/15
86	Install e-cooling	3 mons	Wed 01/07/15
87	Install WIC	1 mon	Mon 03/08/15
88	Cable connections & Interlocks	3 mons	Mon 03/08/15
89	Install instrumentation	2 mons	Tue 01/09/15
90	Vacuum system + ejection towards Gbar	4 mons	Tue 01/09/15
91	Connection AD-ring to ELENA	60 days	Tue 01/12/15
92	Various (connection to cooling; access door, ...)	3 mons	Mon 04/01/16
93	+ Commissioning ELENA	174 days	Fri 01/04/16
96	− Redevelopment TL towards experiments		
97	Installation TL	5 mons	Thu 01/12/16
98	Commissioning ELENA - Experiments	3 mons	Thu 18/05/17
99	+ Installation Gbar		
103	+ Installation BASE	260 days?	Mon 15/04/13



Number of elements (incl spares)

Element	Total number	Of which ready by 06/2015
Quadrupoles electrostatic	100	15
Fast deflectors (incl. extraction)	10	2
Bends electrostatic	16	0
Correctors H/V	44	6
BPM	44	7
Ion switch	1	1

Design to be finished in view of 2015 installation date, except for electrostatic bends

Status – Optics/Integration

- Line geometries fixed
- Integration of lines started
- Position of handover points to be finalized where not fully clear (GBAR, AEGIS, ASACUSA)
- Magnetic shielding to be studied

Status - Hardware

- Design of Fast Deflector, Quadrupoles and Ion Switch in final phase (completion foreseen by 05/2014)
- Ion switch being built in-house (long lead material already ordered); could be tested at Juelich in summer 2014
- Fast Deflector will be built in-house; parts procurement to start in 09/2014
- For Quadrupoles (incl. correctors)
  - Aim for contract to industry for element construction (tentatively 09/2014)
  - Order vacuum chambers separately (tentatively 09/2014)
  - Assure quadrupole assembly into vacuum chambers, cleaning and NEG coating at CERN (2015 -)
- Beam profile monitors (µ-wire monitor used in ASACUSA) taken care of by University of Tokyo collaboration (Masaki Hori) with BE-BI
  - Wire spacing to be defined by 04/2014

Conclusions

- Optics/Integration
  - Available online http://project-elena-optics.web.cern.ch/
  - Finalise BPM positions, error studies, integration, magnetic shielding
- HW design being finalised
- Vacuum
  - The pump-down time urges for a bake-out system (about 300 kCHF)
  - A pressure level of 1e-9 mbar can be reached without NEG and is sufficient for the beam in the lines – **is this pressure level also sufficient for the experiments?**
  - NEG option: about 50 kCHF; manpower available from TE-VSC
  - Sectorizing the vacuum per experiment seems enough
    - Sector valves at each switch and handover point
- Schedule
  - Very tight
  - Need about 15% of equipment by 2015 ready for installation
  - Contract for non in-house equipment planned for 09/2014