Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Legnaro

Ion Beams and Sources at INFN-LNL

A. Facco, head
F. Scarpa, A. Galatà, D. Martini, E. Sattin

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Legnaro

Arguments

- Negative Injector
- Negative Ion Sources
- Negative Beams
- Negative Ion Source Test Bench
- Positive Injector and Source
- Positive Beams

Negative Injector

The Negative Injector is used to produce ion beams suitable to be injected into the electrostatic Tandem Accelerator and then used for experiments in nuclear physic.

Part of the Injector is placed over an insulated platform brought at very high voltage, located inside a closed metal cabinet in order to:

- Give protection against high voltage
- Have the possibility to reduce the air humidity

The working voltage at present is 140 kV.

Negative Injector

External view of the Negative Injector

Negative Injector

The main components of the Injector placed over the platform are the followings:

- The negative sputtering Ion Source.
- The electrostatic Einzel lens.
- The 90° double focusing analysis dipole magnet, R=14”, max field 1.1 T.
- The accelerating tube, 23 electrodes 1” spaced with its resistive voltage divider.

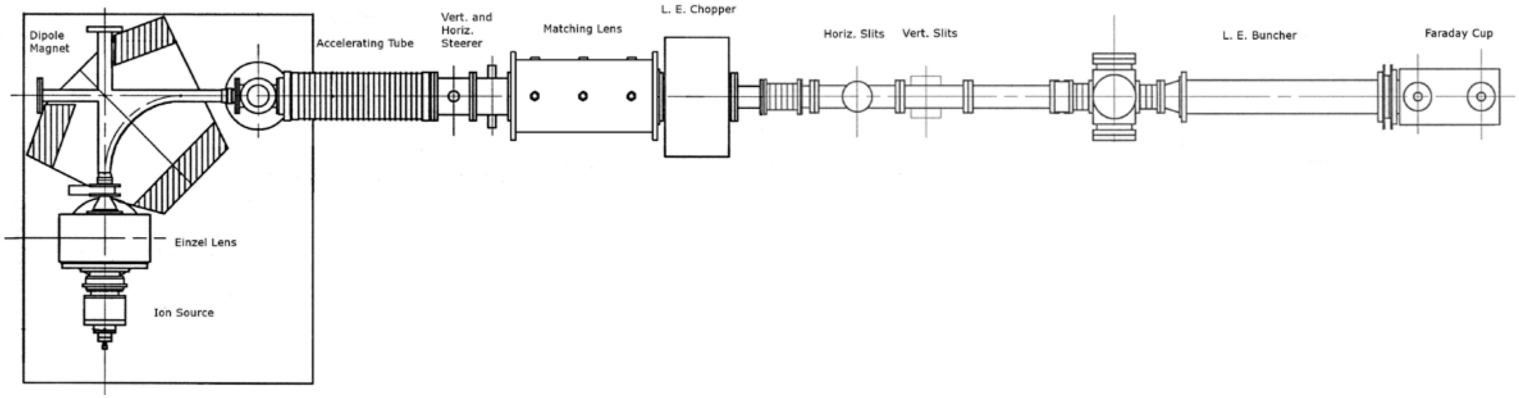
Negative Injector

The main components of the Injector placed outside the cabinet are the followings:

- Electrostatic vertical and horizontal steerers.
- The Matching Lens, electrostatic quadrupol triplet.
- The LE travelling wave Chopper working at 2.5 MHz.
- The vertical and horizontal slits.
- The LE double drift, double harmonic Buncher working at 5 and 10 MHz.
- The LE Faraday Cup.

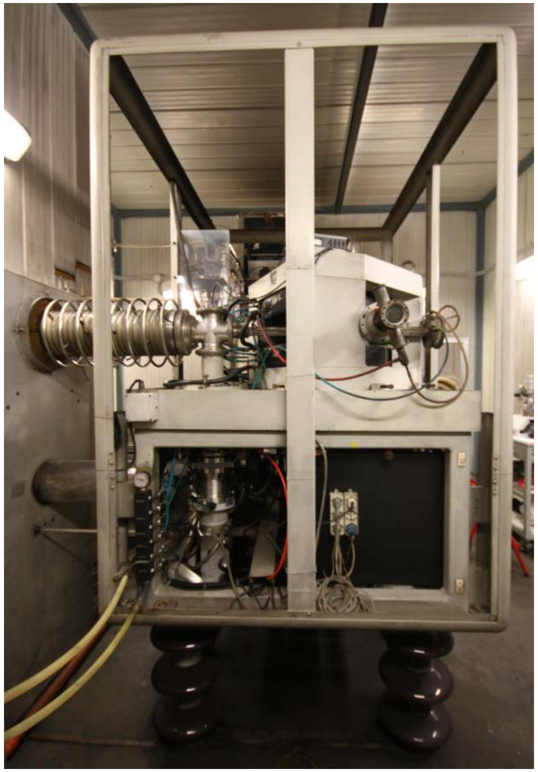
Negative Injector

Schematic view



Negative Injector

Internal view of the Negative Injector



Laboratori Nazionali di Legnaro

Negative Injector

Ancillary systems

- Vacuum: 1 turbo pump system 1000 l/s before the dipole magnet and 1 turbo pump system 450 l/s after the dipole magnet.
- Vacuum measurement and valve control.
- Gas spray system: choice among 8 different gases.
- Cooling water system: deionized water 1000 l/h flow.
- High and low voltage power supplies for the ion source,lenses and magnet located in 2 racks, one of them electrically insulated located inside the cabinet, other racks outside at ground potential.
- Electrical Power: Choice between Motor-Generator or insulation transformer.
- High voltage for preaccelerating tube: 200 kV 1 mA DC high stability power supply located outside the cabinet.

Negative Injector

Laboratori Nazionali di Legnaro

Data acquisition system

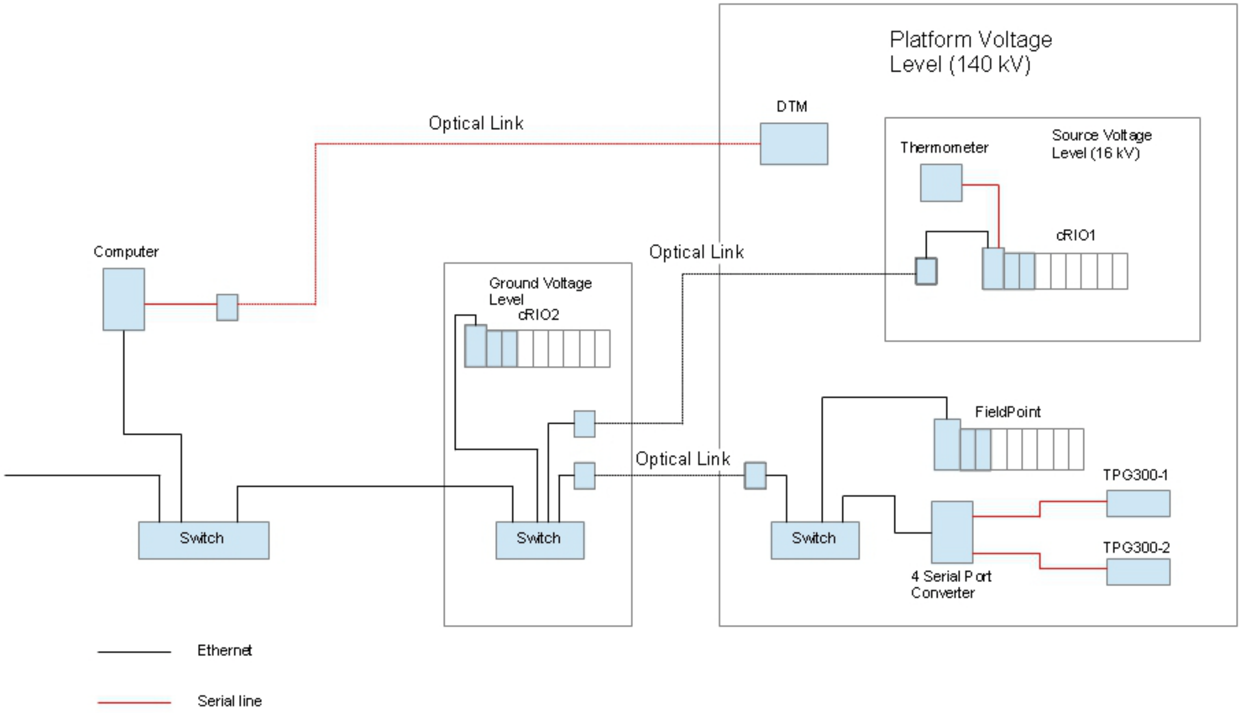
During last year a new data acquisition system for the negative injector has been built and put in operation. The purpose is to replace the old hand-writing parameter recording method and so to have reliable and complete data recording sets displayed also in graphs and charts on the computer screen in order to be able to understand better the behavior and problems that may occur in the injector.

It is built using 3 hardware controllers from National Instruments, one for each potential level, connected to a personal computer via Ethernet connection, programmed using the software LabView.

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Legnaro

Negative Injector

Data acquisition system, block diagram

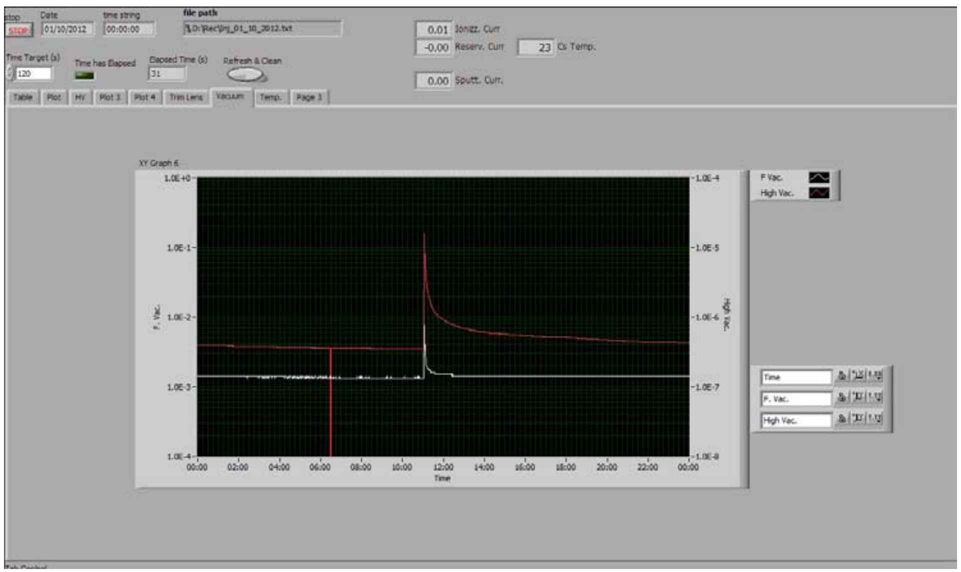


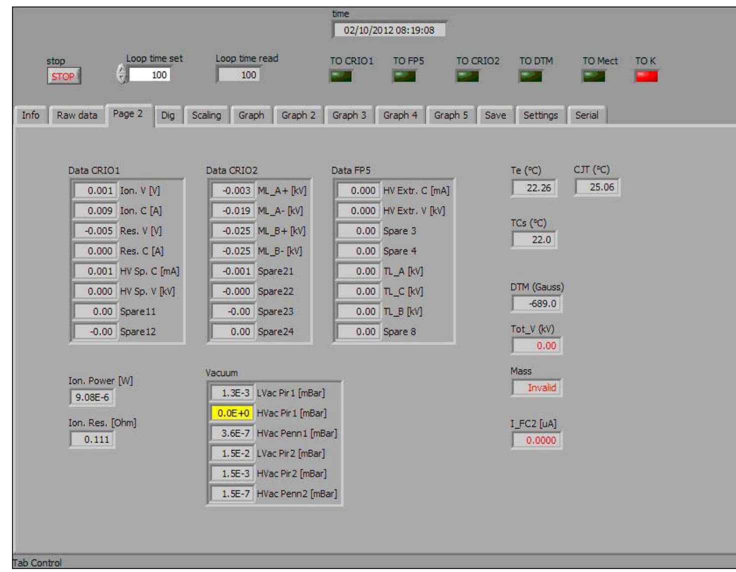
Istituto Nazionale di Fisica Nucleare

Laboratori Nazionali di Legnaro

Negative Injector

Data acquisition system, software

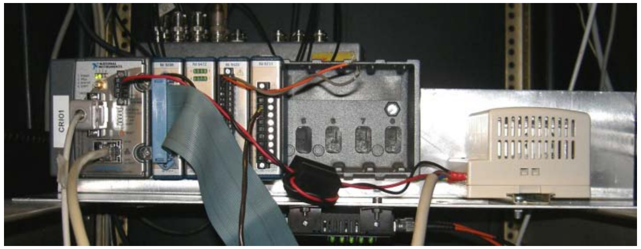




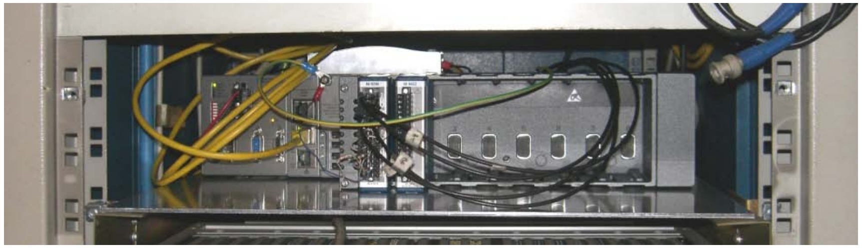
Negative Injector

Data acquisition system, hardware

cRio1

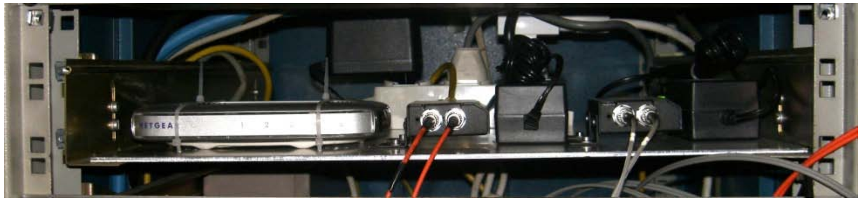


cRio2



FieldPoint

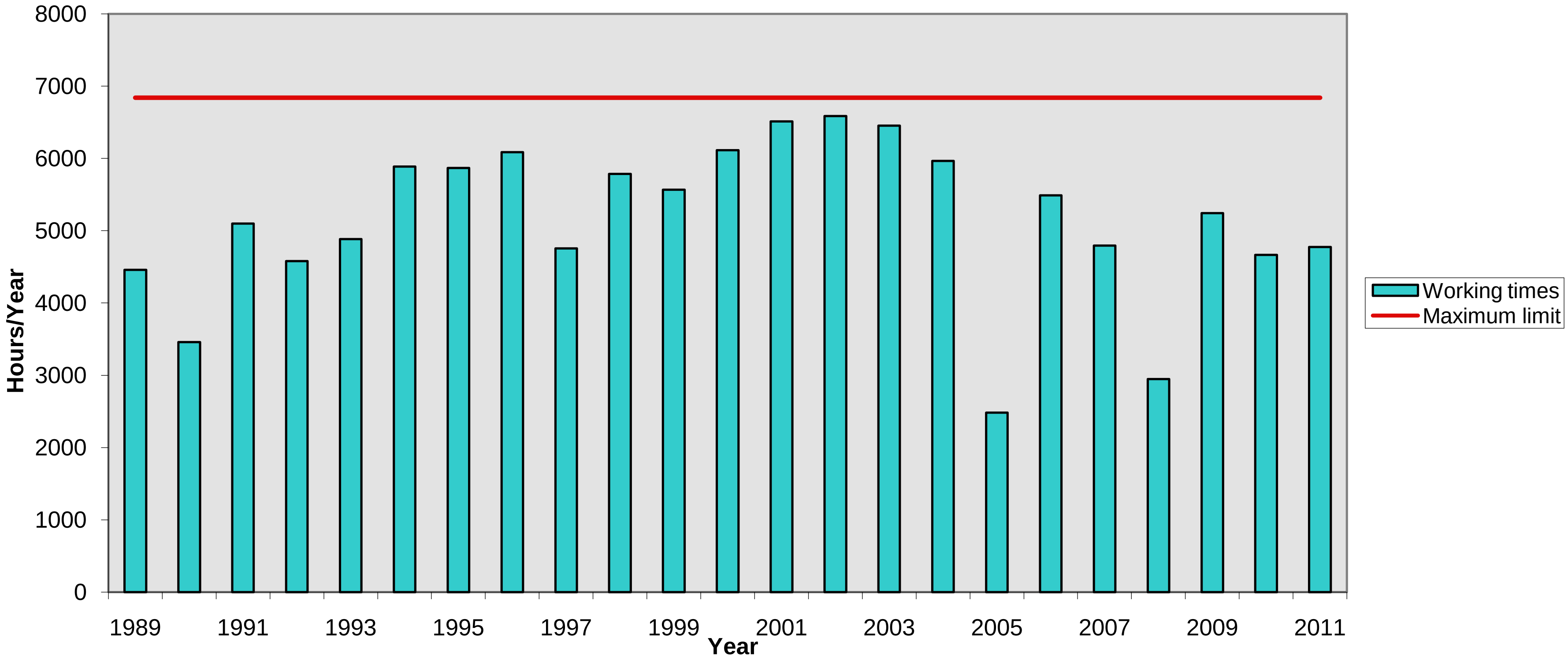
Switch



Fabio Scarpa

Negative Injector

Negative Injector working time

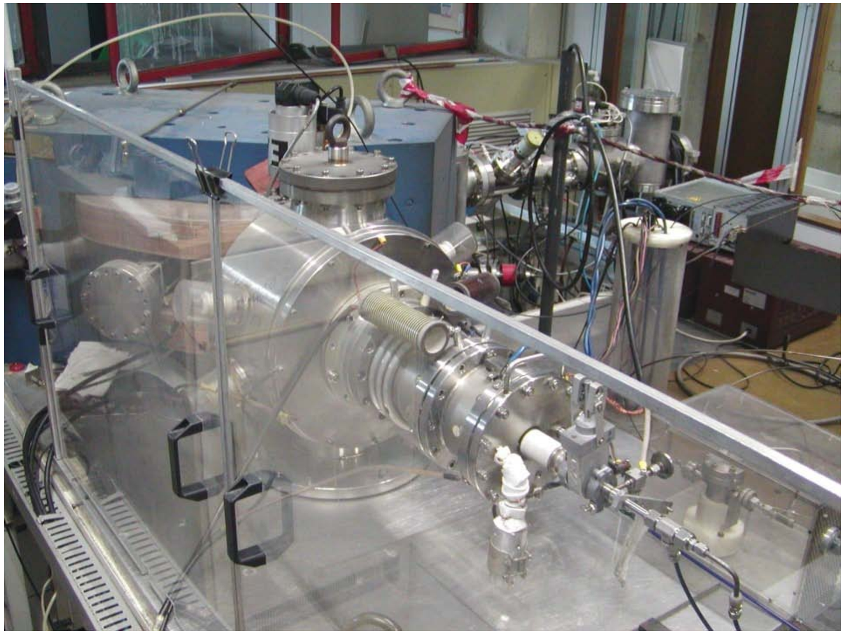


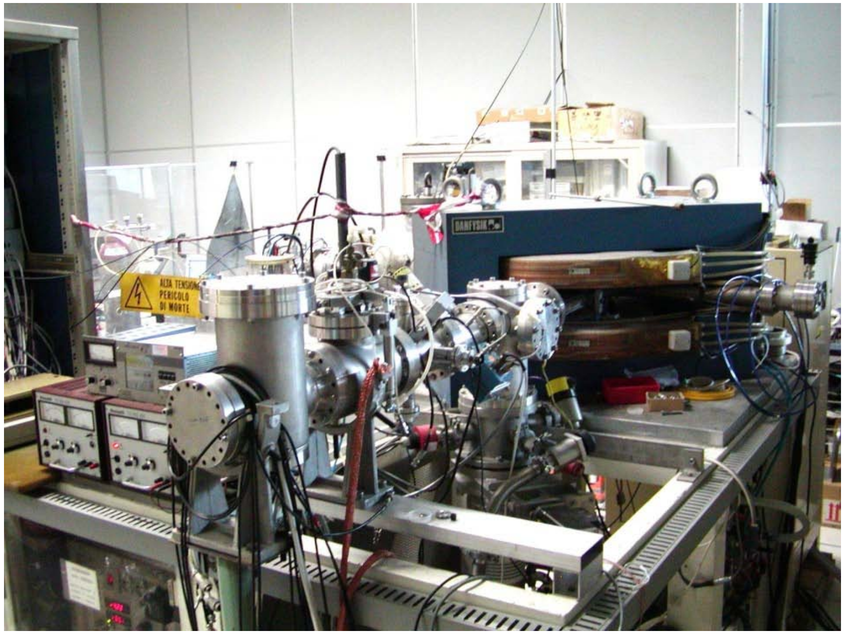
Fabio Scarpa

Istituto Nazionale
di Fisica Nucleare

Laboratori Nazionali di Legnaro

Ion Source Test Bench





Ion Source Test Bench

An Ion Source Test Bench has been built in 1988, it is located into the Source Laboratory. Its functions are the followings:

- Testings of new ion sources
- Developing of new beams out of line
- Possibiliy to perform experiments at very low energy

Its components are the same as the ones in the first part of our Injector, except the preacceleration.

It was very useful for our activity.

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Legnaro

Negative Ion Sources

The negative ion sources now present in the LNL are the following types:

- Hiconex 834
- GIC 860A
- GIC 860C
- NEC SNICS II

They are all Cesium Sputtering types

Negative Ion Sources

Hiconex 834

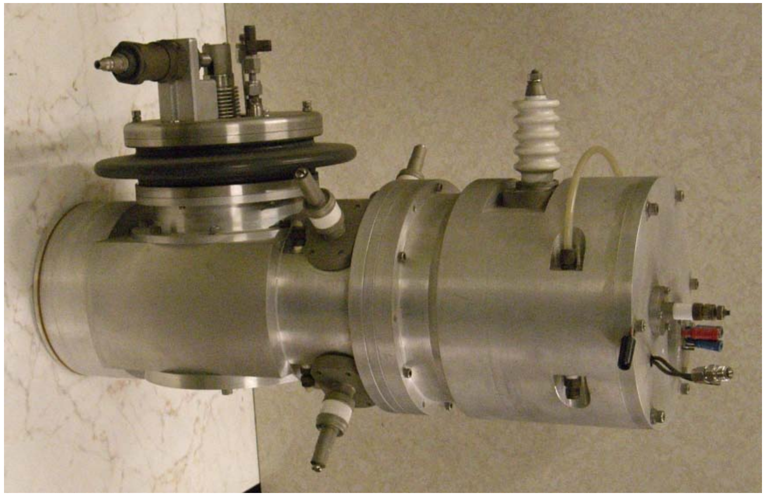
It is the older ion source, it was widely used until 1990 then it was replaced by the 860 types.
It has a target container for 12 targets having the possibility to change target during the runnung, but the target container replacing implies the switch off of the source and the vacuum breakage.
The beam current is relatively low.

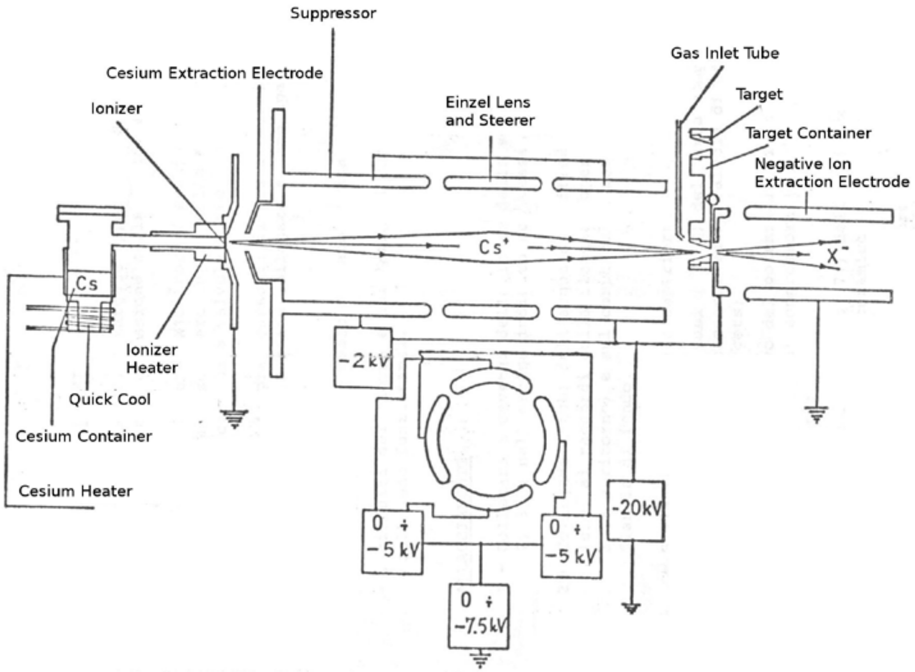
Negative Ion Sources

Istituto Nazionale di Fisica Nucleare

Laboratori Nazionali di Legnaro

GIC 834

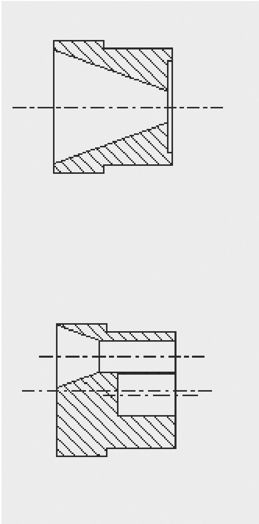




Negative Ion Sources

Targets for Hiconex 834

The first is used for solid materials, like C, Ni, Cu, ecc..
The second one is used for materials in form of powder pressed inside the hole.



Negative Ion Sources

Laboratori Nazionali di Legnaro

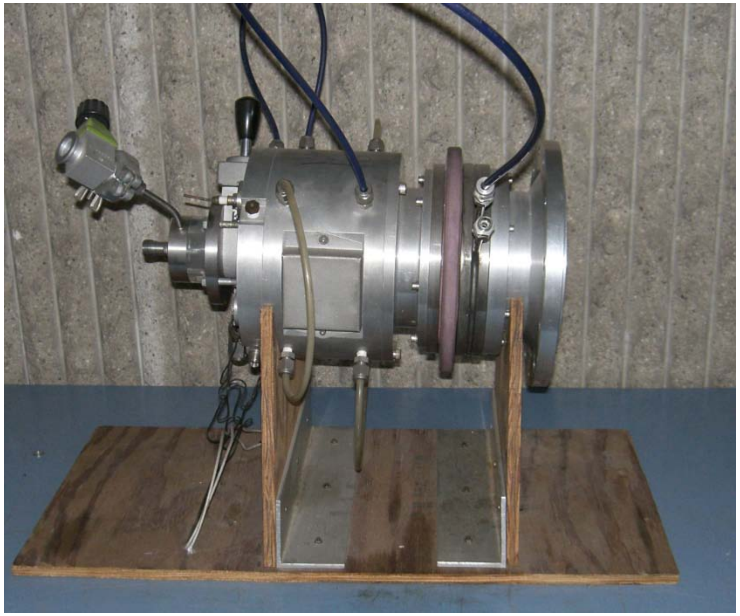
GIC 860A

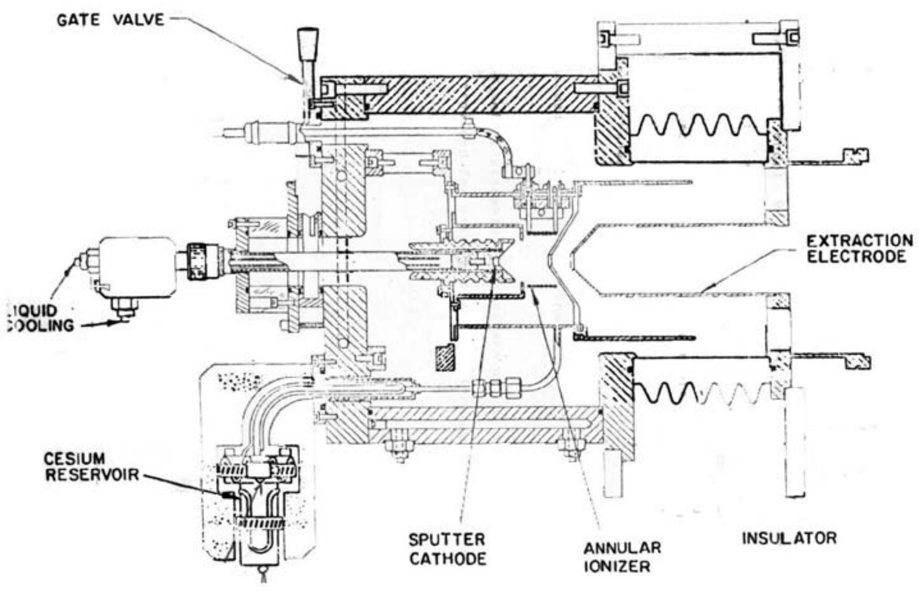
It was used for several years just after the 834.
It has an helical ionizer.
It has one target only, but the target replacement is very fast and doesn't involve the vacuum breakage.
The beam current is almost one order of magnitude higher than the previous source.
It is lighter and smaller than the 834.
The operation is a little bit easier having less controls.

Negative Ion Sources

Laboratori Nazionali di Legnaro

GIC 860A





Negative Ion Sources

GIC 860C

It is the only source used at present. We have 2 items, one is in use while the other is on maintenance.

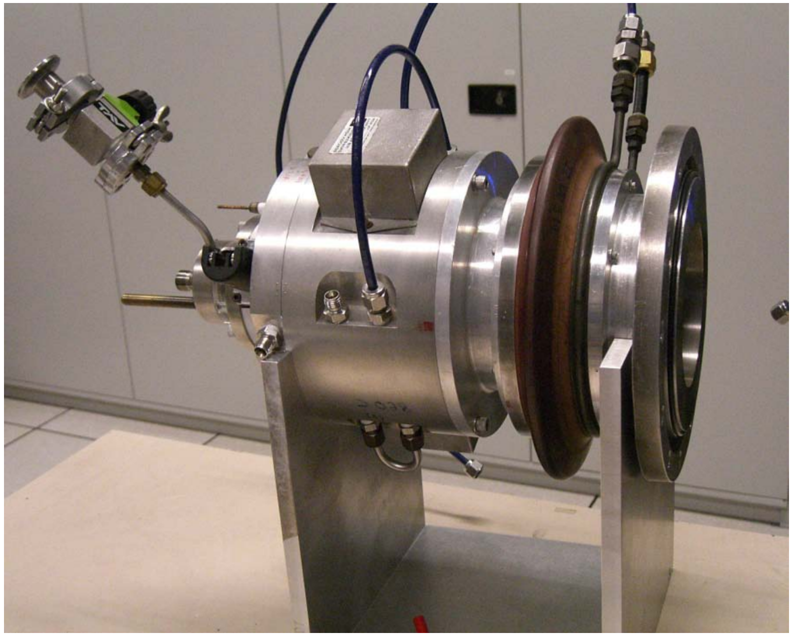
It is similar to the 860A type except the ionizer that in this case has a spherical shape. For this reason the ion beam has a high central brightness and can be injected into the Tandem accelerator with minimal loading and loss.

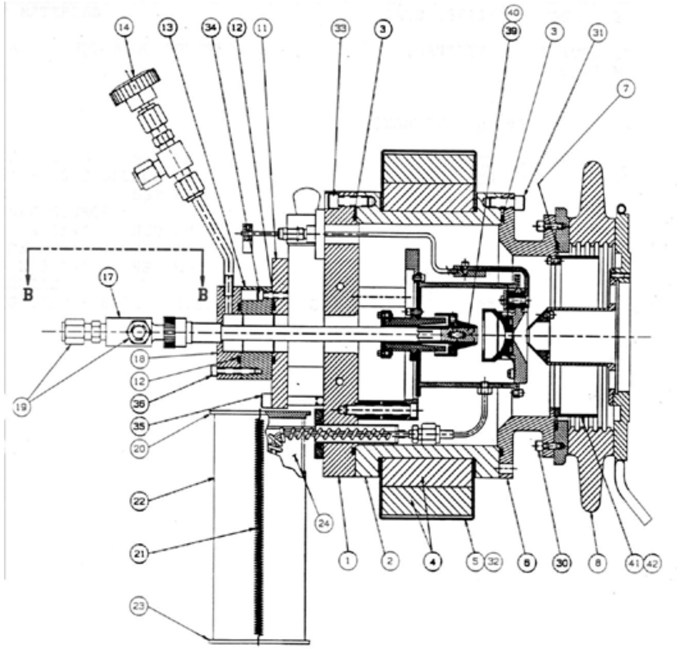
The beam intensity is almost the same as the 860A type.

The operation is easy.

Negative Ion Sources

GIC 860C





Laboratori Nazionali di Legnaro

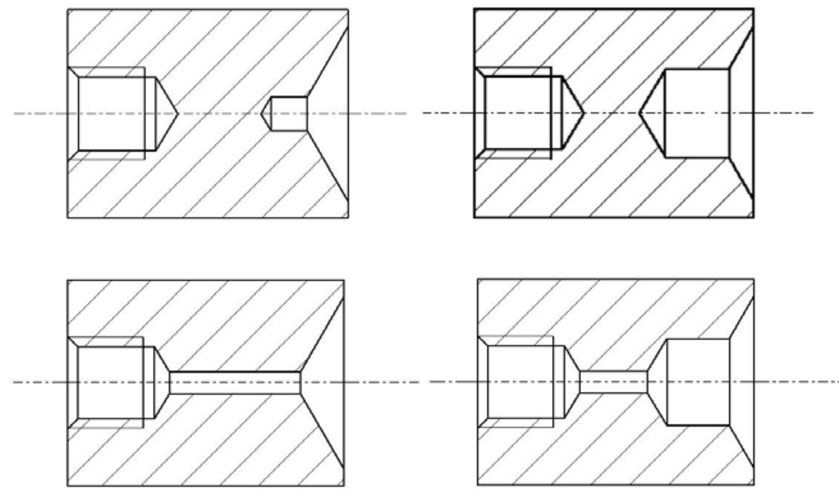
Negative Ion Sources

Targets for GIC 860A and 860C

Targets for solid material | Targets for sample insert

Targets without gas spray

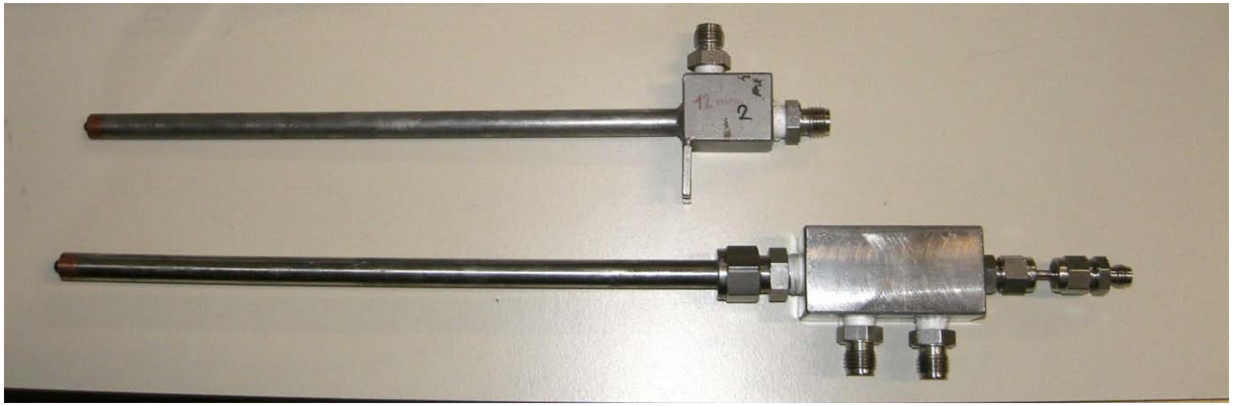
Targets for gas spray



Istituto Nazionale
di Fisica Nucleare
Laboratori Nazionali di Legnaro

Negative Ion Sources

GIC 860C, target holders



Without gas spray

With gas spray

Negative Ion Sources

SNICS II

It is similar to the 860 family, and it was used in the past alternating with the 860 types.

The ionizer has a conical shape and has a little bit larger dimensions than the 860 types.

The Ionizer power is about the double with respect to the 860, and the external walls aren't cooled. This makes the internal temperature higher so that some target materials with relatively high vapor pressure , like Ca and Mg, show higher consumption rate due to sublimation, and sometime can't be used, but for the other the efficiency is good.

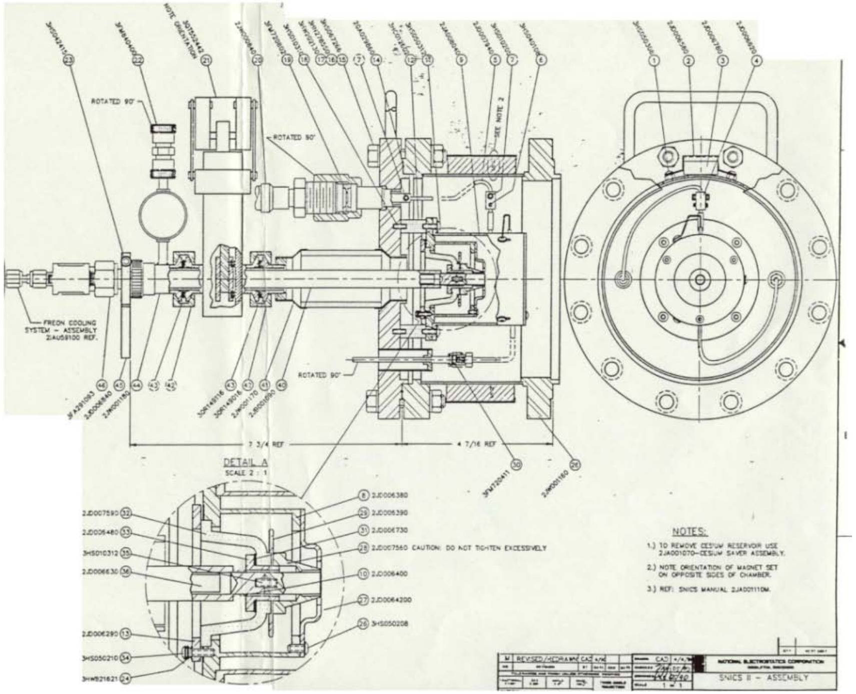
The targets are similar to the ones for the 860, they have only a little bit different dimensions

INFN
Istituto Nazionale
di Fisica Nucleare

Laboratori Nazionali di Legnaro

Negative Ion Sources

SNICS II



Negative Ion Beams

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Legnaro

An updated list of all available beams at the LNL Tandem accelerator can be found in the web site of our Laboratory.

It includes 82 isotopic species routinely produced. Some of these require rare isotopic material and must be provided by the users.

Some elements have a poor electron affinity so don’t form negative ions, in this case a cluster must be produced. The second column of the list shows the form of this cluster.

Istituto Nazionale di Fisica Nucleare

Laboratori Nazionali di Legnaro

The quoted intensity should be intended as an average value that can be reliably maintained during a long run without making unreasonably short the Tandem stripper foils lifetime.

Table 1. Available Beams at LNL Tandem Injector

Positive Beam	Negative Beam	Current in FC 2 [nA]	Comments
^{1}H	^{1}H	1000	
^{2}H	^{2}H	300	Deuterium Gas
^{6}Li	^{6}Li	40	
^{7}Li	^{7}Li	200	
^{10}B	^{10}B	50	
^{11}B	^{11}B	200	
^{12}C	^{12}C	1000	
^{13}C	^{13}C	30	
^{14}N	^{25}(BN)	500	
^{16}O	^{16}O	1500	
^{17}O	^{17}O	500	^{17}O Gas – Contact Staff
^{18}O	^{18}O	500	
^{19}F	^{19}F	1000	
^{24}Mg	^{25}(MgH)	100	
^{26}Mg	^{27}(MgH)	100	Contact Staff
^{27}Al	^{27}Al	300	
^{28}Si	^{28}Si	1000	
^{29}Si	^{29}Si	200	
^{30}Si	^{30}Si	150	Contact Staff
^{31}P	^{31}P	400	
^{32}S	^{32}S	1000	
^{33}S	^{33}S	300	Contact Staff
^{34}S	^{34}S	150	
^{36}S	^{36}S	300	Contact Staff
^{35}Cl	^{35}Cl	1000	
^{37}Cl	^{37}Cl	500	
^{40}Ca	^{41}(CaH)	80	
^{42}Ca	^{43}(CaH)	80	Contact Staff
^{48}Ca	^{49}(CaH)	80	Contact Staff
^{48}Ti	^{49}(TiH)	500	
^{50}Cr	^{52}(CrH$_2$)	80	Contact Staff
^{52}Cr	^{54}(CrH$_2$)	80	
^{51}V	^{51}V	200	
^{51}V	^{67}(VO)	400	
^{54}Fe	^{54}Fe	100	Contact Staff
^{56}Fe	^{56}Fe	100	
^{58}Ni	^{58}Ni	1000	
^{60}Ni	^{60}Ni	500	
^{64}Ni	^{64}Ni	500	Contact Staff
^{63}Cu	^{63}Cu	700	
^{65}Cu	^{65}Cu	300	

Positive Beam	Negative Beam	Current in FC 2 [nA]	Comments
^{64}Zn	^{80}(ZnO)	400	
^{66}Zn	^{82}(ZnO)	200	
^{68}Zn	^{84}(ZnO)	200	
^{70}Zn	^{86}(ZnO)	200	Contact Staff
^{69}Ga	^{85}(GaO)	200	
^{71}Ga	^{87}(GaO)	150	
^{74}Ge	^{74}Ge	400	
^{76}Ge	^{76}Ge	150	Contact Staff
^{74}Se	^{74}Se	300	
^{76}Se	^{76}Se	150	
^{77}Se	^{77}Se	200	
^{78}Se	^{78}Se	300	
^{80}Se	^{80}Se	300	
^{82}Se	^{82}Se	300	Contact Staff
^{79}Br	^{79}Br	300	
^{81}Br	^{81}Br	300	
^{90}Zr	^{91}(ZrH)	80	
^{91}Zr	^{92}(ZrH)	30	
^{92}Zr	^{93}(ZrH)	25	
^{94}Zr	^{95}(ZrH)	25	
^{96}Zr	^{112}(ZrO)	200	Contact Staff
^{92}Mo	^{108}(MoO)	200	
^{94}Mo	^{110}(MoO)	120	
^{95}Mo	^{111}(MoO)	200	
^{96}Mo	^{112}(MoO)	200	
^{97}Mo	^{113}(MoO)	120	
^{98}Mo	^{114}(MoO)	200	
^{100}Mo	^{116}(MoO)	120	
^{96}Ru	^{96}Ru	150	
^{98}Ru	^{98}Ru	50	
^{99}Ru	^{99}Ru	200	
^{100}Ru	^{100}Ru	200	
^{101}Ru	^{101}Ru	200	
^{102}Ru	^{102}Ru	200	
^{104}Ru	^{104}Ru	200	
^{107}Ag	^{107}Ag	200	
^{109}Ag	^{109}Ag	200	
^{116}Sn	^{116}Sn	150	
^{120}Sn	^{120}Sn	150	
^{127}I	^{127}I	150	
^{197}Au	^{197}Au	150	Contact Staff

Negative Ion Beams

Requirements fot rare isotope materials

Isotope	Average beam time per target	Required amount per target	Required enrichment (minimum)	Format
	Days	mg	%	
^{17}O	-	-	60	Gas, please contact the staff
^{26}Mg	4	40	97	Powder
^{33}S	7	20	50	Powder
^{36}S	7	20	69	Powder
^{42}Ca **	7	25	97	Metal cylinder
^{48}Ca **	7	25	97	Metal cylinder
^{50}Cr	3	70	96	Powder
^{54}Fe	2,3	70	80	Metal cylinder
^{64}Ni	7	80	50	Powder
^{74}Se	7	100	30	CdSe Powder
^{96}Zr	7	80	60	ZrO Powder

** The ^{42}Ca and ^{48}Ca material must be delivered inserted in the proper support (available at *Servizio Sorgenti e Iniettori*) with an axial hole with diameter between 0.5 mm and 0.8 mm to allow for Ammonia gas flow.

Negative Ion Beams

Ca beams

Calcium is very difficult to produce as negative beam for the following reasons:

- It has a poor electron affinity, so a cluster must be produced.
- The usable materials are very sensitive to Oxygen and moisture so they are easy to alterate resulting in very low beam production efficiency. Care must be taken in storing these materials.
- The ion source may be critical to operate, it may go sometimes in uncontrollable situation.

Laboratori Nazionali di Legnaro

Negative Ion Beams

Ca beams, production methods

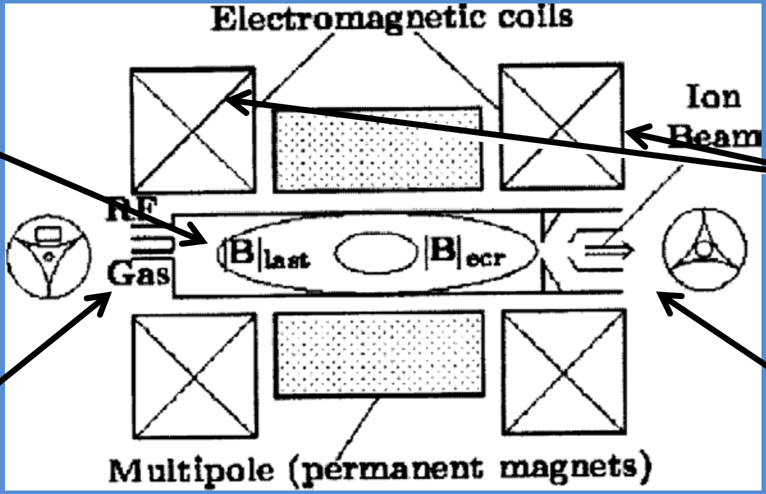
We have used 2 methods to produce negative Ca beams:

- Using CaH2 compound.
  - Advantages:
    - is easier, it hasn't gas spray
    - the material can withstand to relatively high temperature
    - the production efficiency is good
  - Disadvantages
    - it is very sensitive to Oxygen and humidity so it is diffcult to store
    - it is less suitable for rare isotope.

- Using metallic Ca plus ammonia spray.
  - Advantages
    - the material is less sensitive to Oxygen and humidity
    - the production efficiency is good as well
    - it is more suitable for rare isotope
  - Disadvantages
    - It may be a little bit more complicated

POSITIVE ION SOURCE: ECRIS

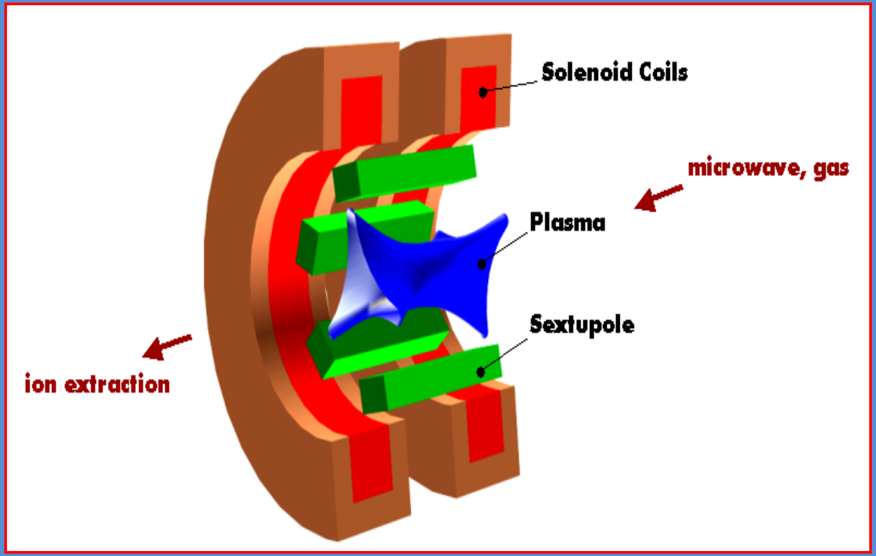
PLASMA CHAMBER



MAGNETIC SYSTEM:Coils (axial field), Multipole (radial field) = <u>B-Minimum Configuration</u>

INJECTION:
Microwave @ 14÷28 GHz
gas and oven

ION EXTRACTION



CHARACTERISTICS

- Reliability
- Reproducibility
- Good Beam Quality
- High Currents of Medium-High Charge States
- DC and Pulsed

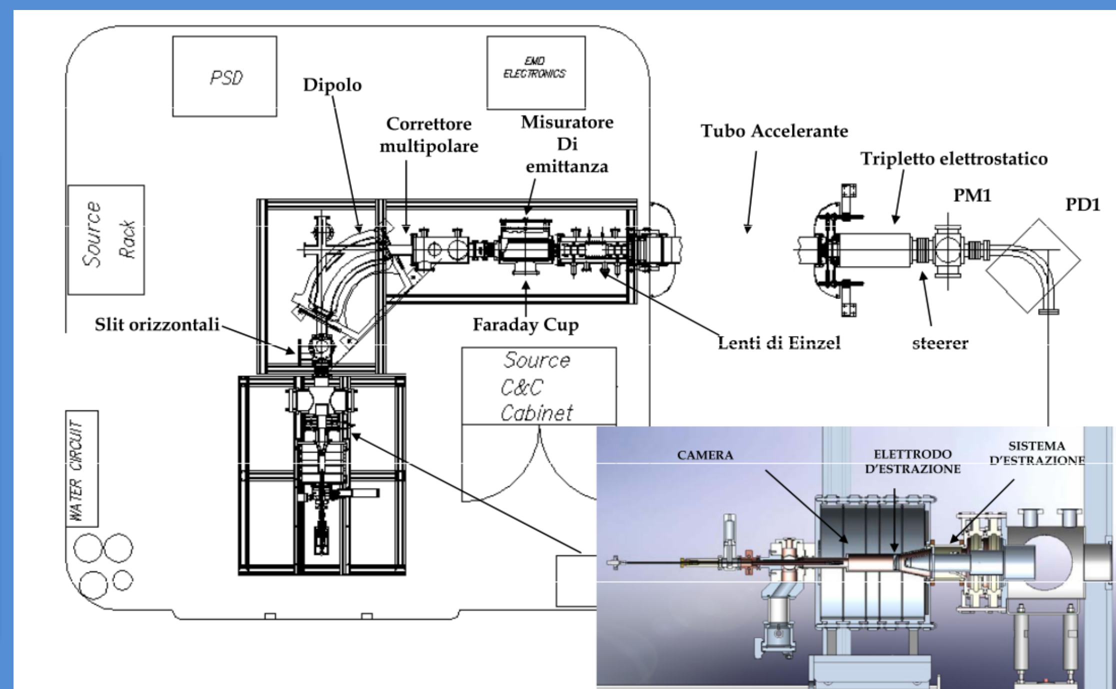
ECRIS @ LNL: LEGIS
(LEGnaro ecrIS)

SUPERNANOGAN FROM PANTECHNIK

- Simple Design
- Low Power Consumption (full permanent magnet)
- Good Performances

β(PIAVE)=0.0089

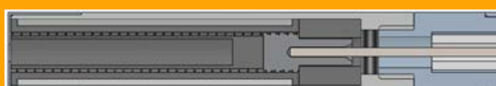
HV PLATFORM
- Square 4.5x4.5 m2
- Maximum Voltage: 350kV
- Operative Voltage: ~200kV
- Transformer: max power 135KVA up to 400kV



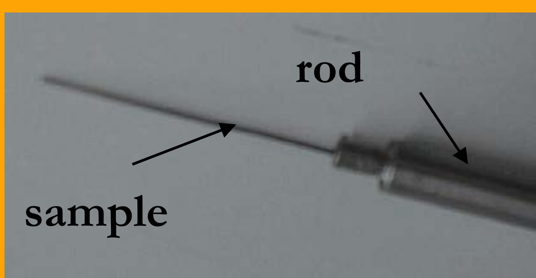
ION BEAMS FROM LEGIS

PRODUCED FROM:

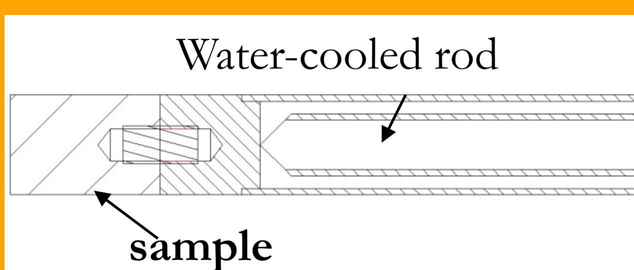
- **GAS**
- **METALLIC VAPOURS**



OVEN

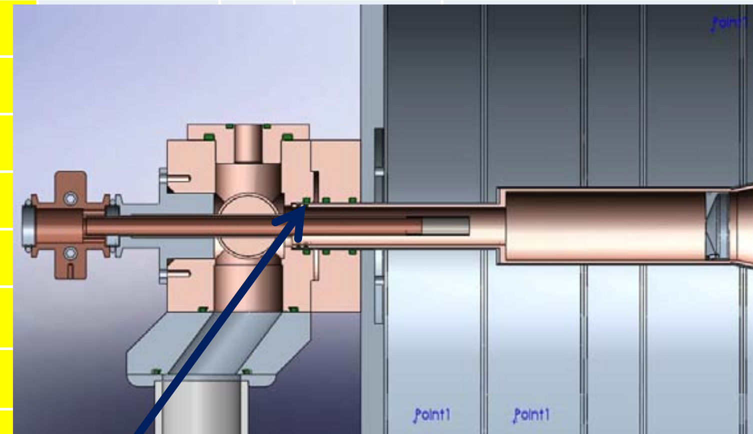


DIRECT INSERTION



SPUTTERING

Beam	A	Q	I[pnA]	Enriched isotope?
O	16	7	>280	No
O				
Ne				
Ne				
Ar				
Ar				
Zn				
Zn				
Zn	[illegible]	[illegible]	[illegible]	[illegible]
Zn	66	15	200	No
Zn	All	17	235	Si
Zn	66	17	117	No
Kr	All	14	710	Si
Kr	All	15	330	Si
Nb	93	16	>100	No
Sn	All	21	90	Si
Xe	All	26	150	Si
Xe	All	27	74	Si
Sm	All	26	100	Si
Au	197	30	65	Si



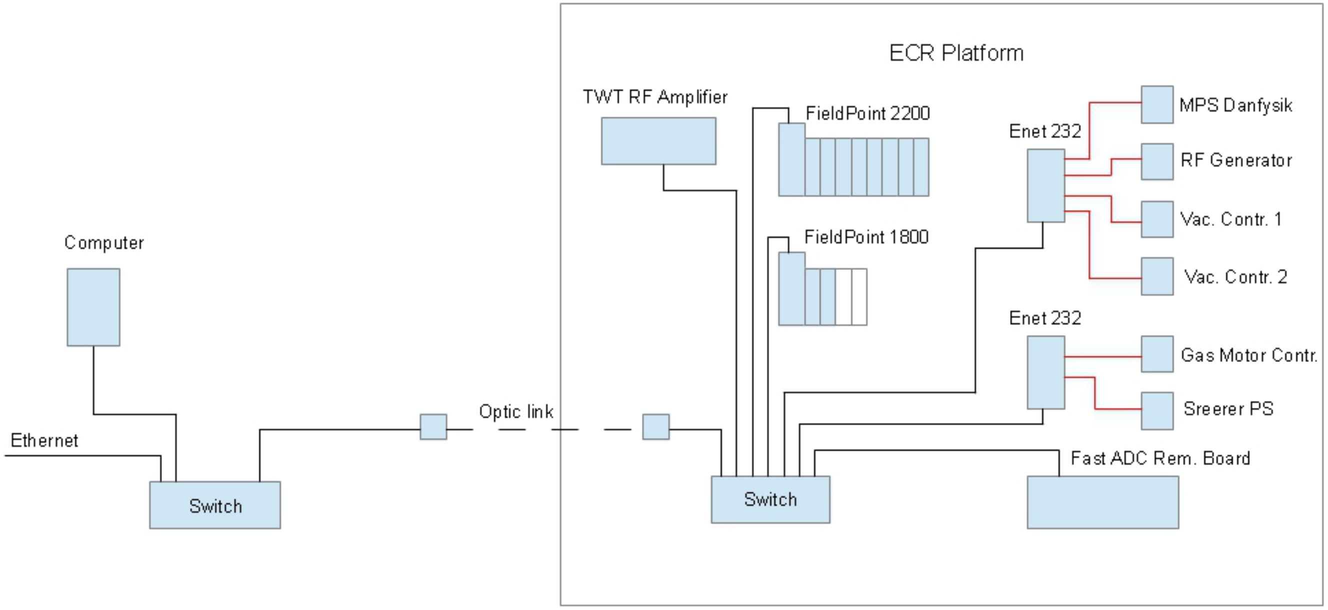
Positive Ion Beams

The reported beam current is referred to the beam extracted from the ion source and injected in the PIAVE Injector. The quoted intensity should be intended as an average value that can be reasonably maintained during a long run.

Beam	Z	A	Charge State	Beam Current		Comments
				[nA]	[pnA]	
C	6	12	+4	4000	1000	The user must provide the enriched isotope (*)
C	6	13	+4	4000	1000	The user must provide the enriched isotope (*)
N	7	14	+4	4000	1000	-
N	7	15	+3	3000	1000	-
N	7	15	+4	4000	1000	The user must provide the enriched isotope (*)
O	8	16	+7	>2000	>280	-
O	8	17, 18	+7	>2000	>280	The user must provide the enriched isotope (*)
Ne	10	20, 22	+4	>5000	>1250	-
Ne	10	20, 22	+5	>5000	>1000	-
Mg	12	24	+7	>400	>55	-
Mg	12	25	+7	>400	>55	The user must provide the enriched isotope (*)
Mg	12	26	+7	>400	>55	The user must provide the enriched isotope (*)
Ar	18	36, 38	+9	>2000	>220	The user must provide the enriched isotope (*)
Ar	18	40	+9	>2000	>220	-
Zn	30	64	+11	3000	272	-
Zn	30	64	+15	6000	400	The user must provide the enriched isotope (*)
Zn	30	64	+17	4000	235	The user must provide the enriched isotope (*)
Zn	30	66	+15	3000	200	-
Zn	30	66	+15	6000	400	The user must provide the enriched isotope (*)
Zn	30	66	+17	2000	117	-
Zn	30	66	+17	4000	235	The user must provide the enriched isotope (*)
Zn	30	67	+15	6000	400	The user must provide the enriched isotope (*)
Zn	30	67	+17	4000	235	The user must provide the enriched isotope (*)
Zn	30	68	+13	2000	154	-
Zn	30	68	+15	6000	400	The user must provide the enriched isotope (*)
Zn	30	68	+17	4000	235	The user must provide the enriched isotope (*)
Kr	36	All	+14	10000	710	The user must provide the enriched isotope (*)
Kr	36	All	+15	5000	330	The user must provide the enriched isotope (*)
Nb	41	93	+16	>1600	>100	-
Sn	50	All	+21	2000	90	The user must provide the enriched isotope (*)
Xe	54	All	+26	4000	150	The user must provide the enriched isotope (*)
Xe	54	All	+27	2000	74	The user must provide the enriched isotope (*)
Sm	62	All	+26	2600	100	The user must provide the enriched isotope (*)
Au	79	197	+30	2000	65	The user must provide the material (*)

Positive Ion Beams

ECR Control System - Hardware

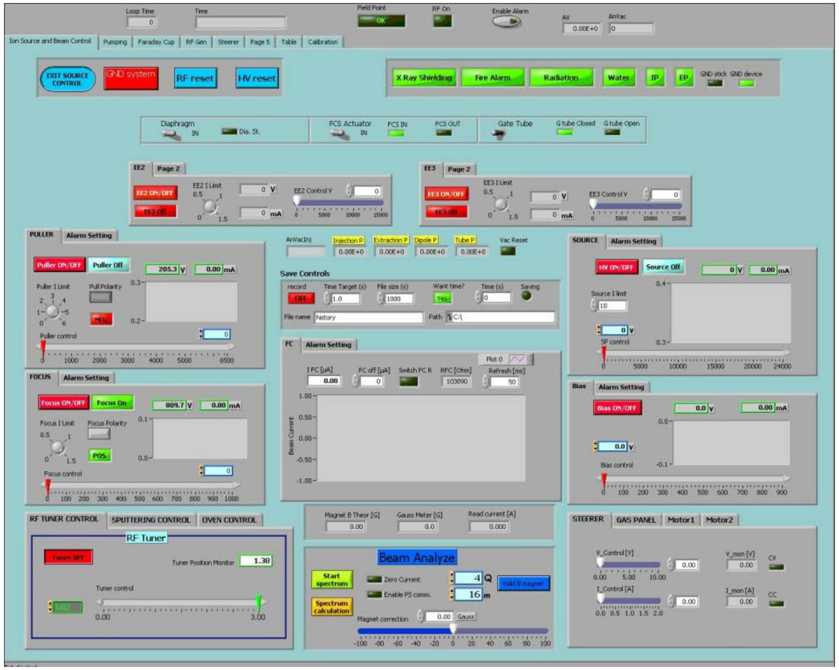


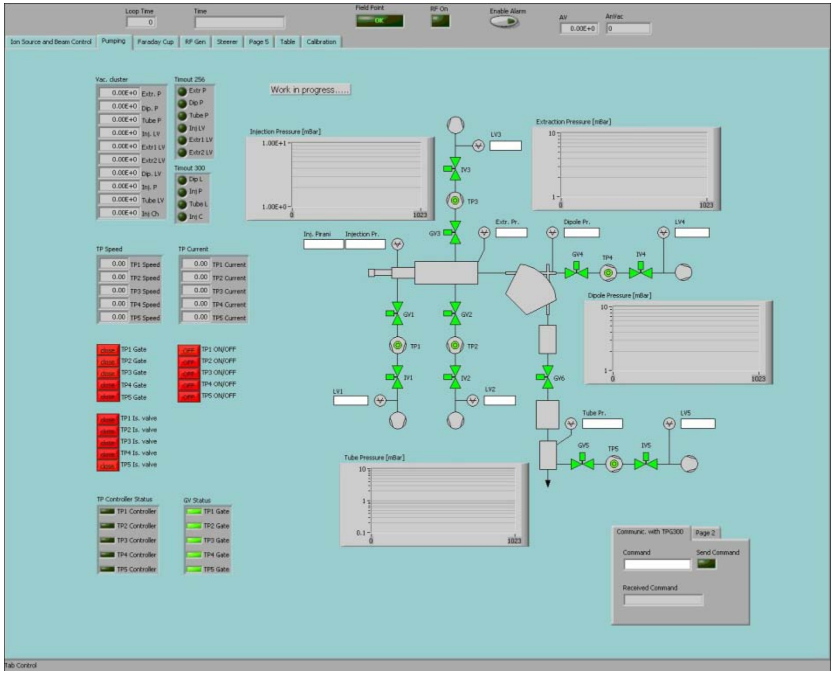
Laboratori Nazionali di Legnaro

Positive Ion Beams

ECR Control System - Software

The software has been completely re-written using still LabView





Fabio Scarpa

Conclusions

Negative Injector

- 82 beams are available until now, it is possible to increase this number making a request to the staff in order to start a new development

Positive Injector

- 13 beams are available until now, other are under development and will be ready soon.