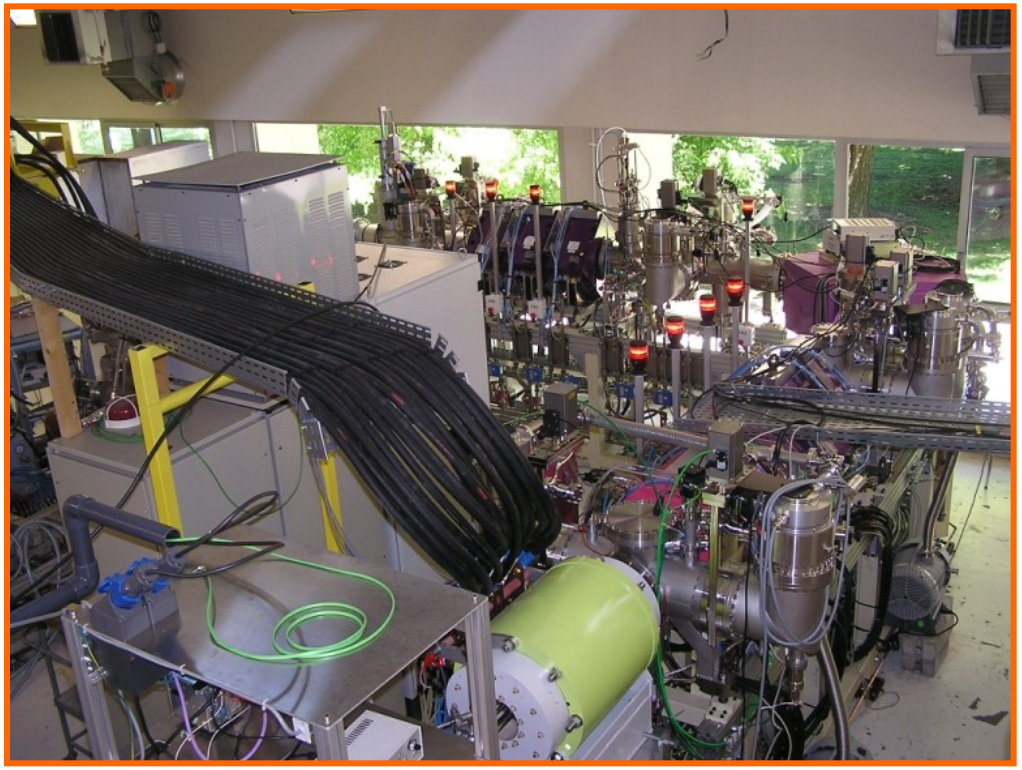
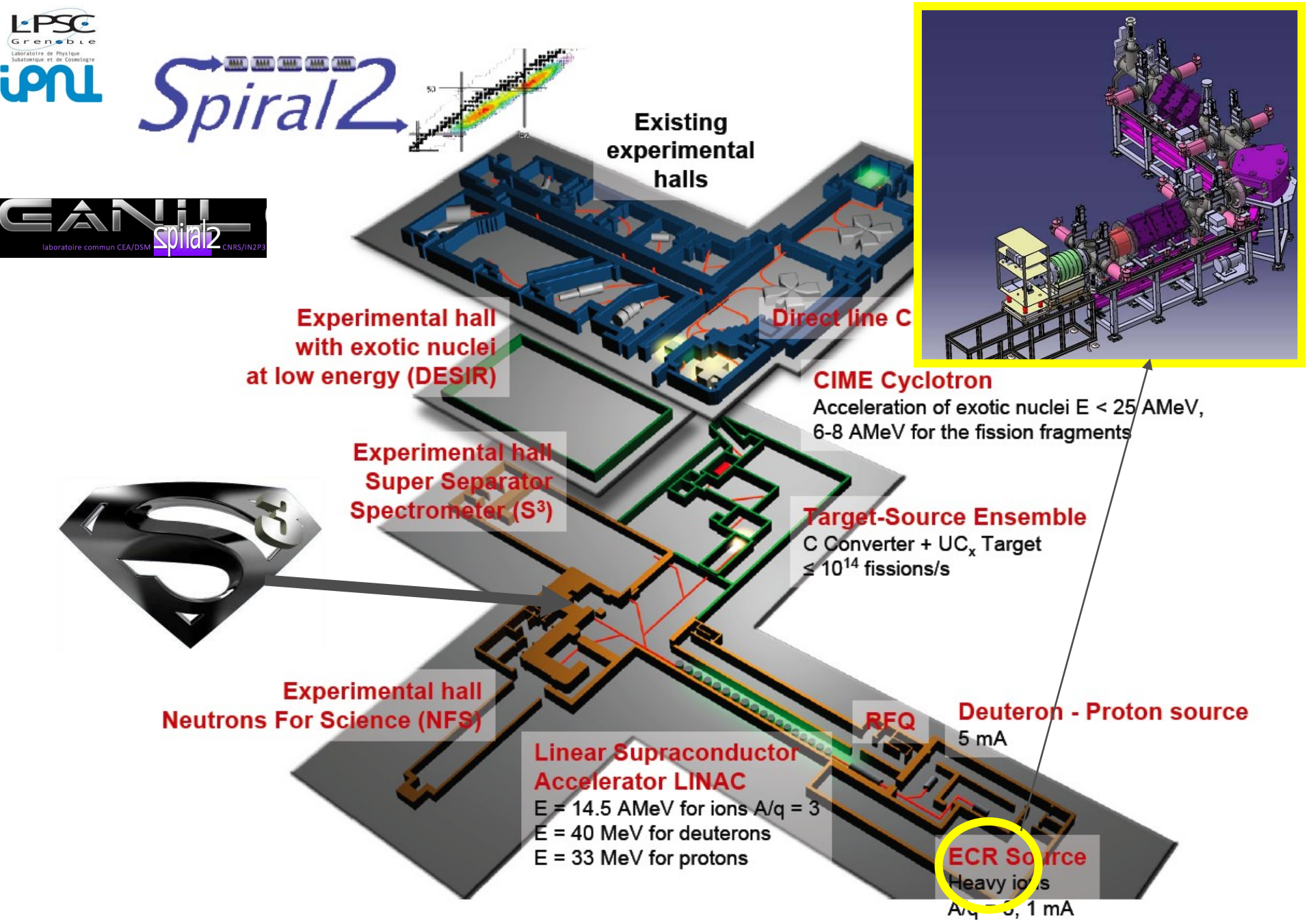
First A/Q=3 beams of Phoenix V2 on the heavy ion low energy beam transport line of Spiral2

C.Peaucelle[1],T.Thuillier[2], T.Lamy[2], P. Grandemange[2], J.Angot[2], J-L. Biarrotte[3], D. Uriot[4]

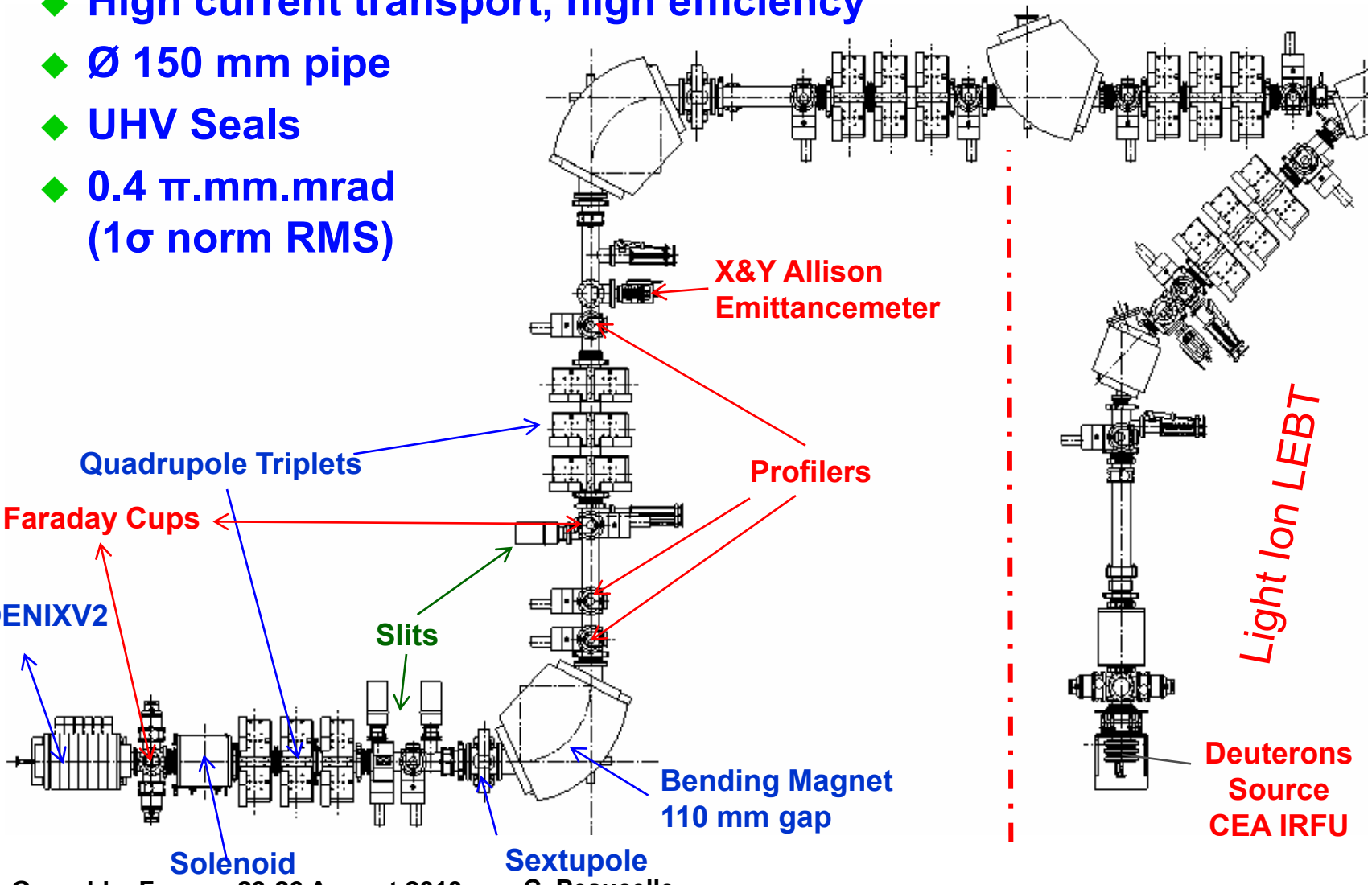
[1)] IPNL, [2)] LPSC, [3)] IPNO, [4)] CEA/irfu




Existing experimental halls
Experimental hall with exotic nuclei at low energy (DESIR)
Direct line C
CIME Cyclotron
Acceleration of exotic nuclei E < 25 AMeV, 6-8 AMeV for the fission fragments
Experimental hall Super Separator Spectrometer (S3)
Target-Source Ensemble
C Converter + UCx Target
≤ 10^14 fissions/s
Experimental hall Neutrons For Science (NFS)
RFQ
Deuteron - Proton source
5 mA
Linear Supraconductor Accelerator LINAC
E = 14.5 AMeV for ions A/q = 3
E = 40 MeV for deuterons
E = 33 MeV for protons
ECR Source
Heavy ions
A/q = 3, 1 mA

The Heavy Ion Low Energy Beam Transport Line

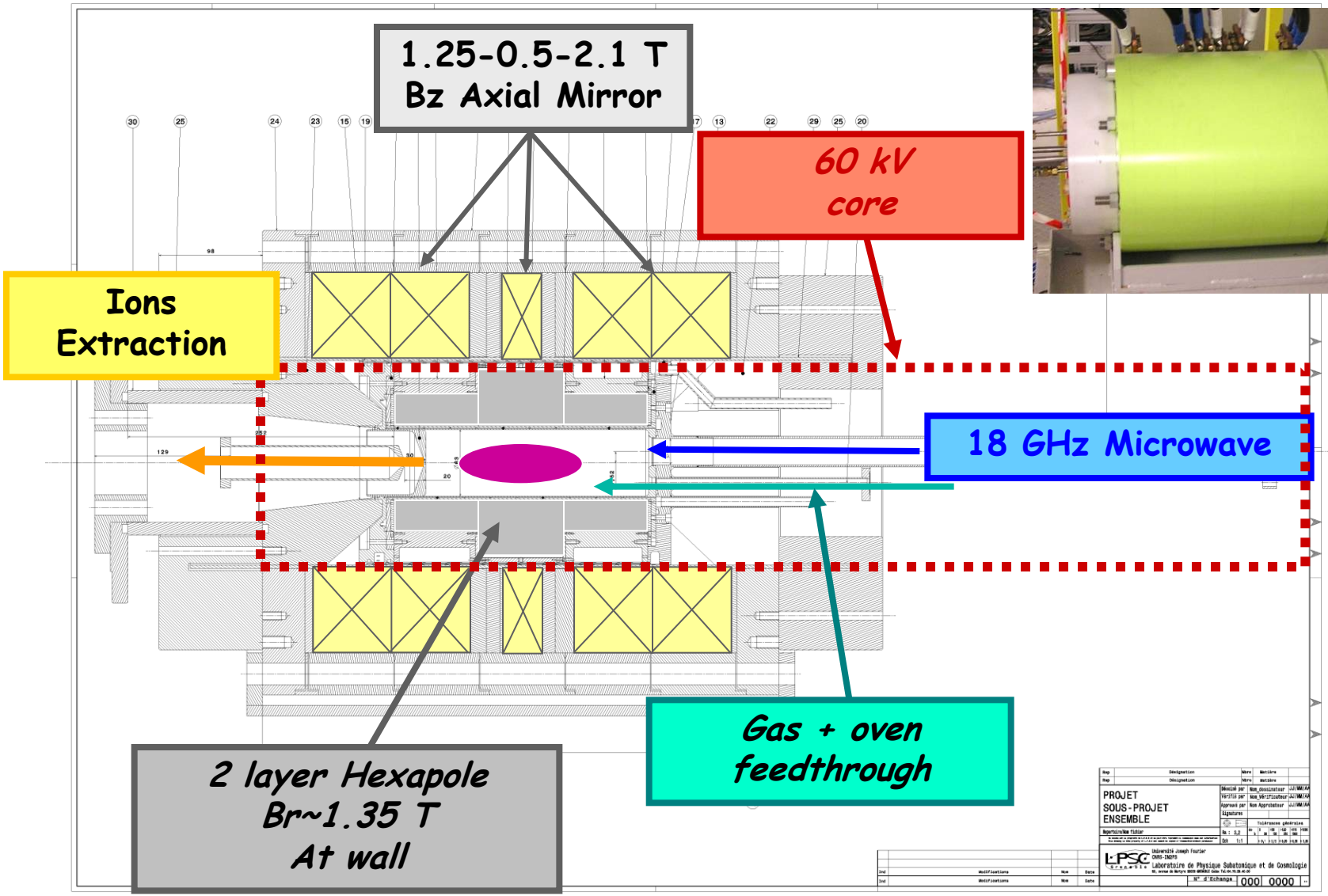
- **Calculated and designed by CEA, GANIL, IPNO**
  - **High current transport, high efficiency**
  - **Ø 150 mm pipe**
  - **UHV Seals**
  - **0.4 π.mm.mrad (1σ norm RMS)**



Objectives on the LEBT

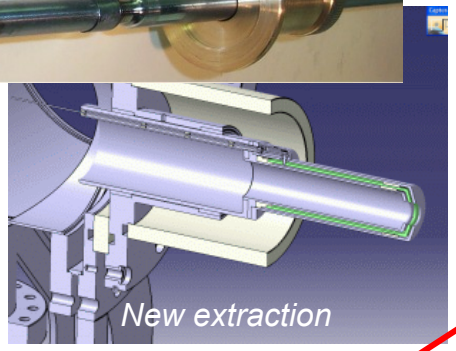
- **Commissioning 2010/2011**
  - Automats
  - Faraday cups, profilers, emittancemeters, slits
  - Vacuum
  - Command control (EPICS)
  - Optics commissioning, spectrum
  - ECRIS Commissioning : PHOENIX V2 @ 18 GHz
    - ☞ Extraction at 60 kV
    - ☞ Ar, O, He, Ne , S, Si , Ca… A/Q=3
  - Emittance measurements and feedback with TRACEWIN to check transport code
- **Moving to Spiral2 in end of 2011**
- **Starting up in mid or end 2012 at GANIL**

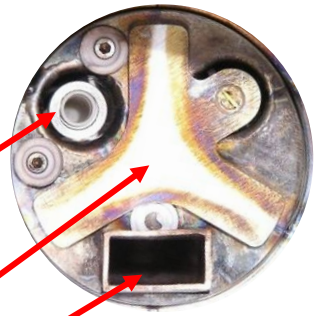
PHOENIX V2 : First ECRIS on Spiral2 LEBT



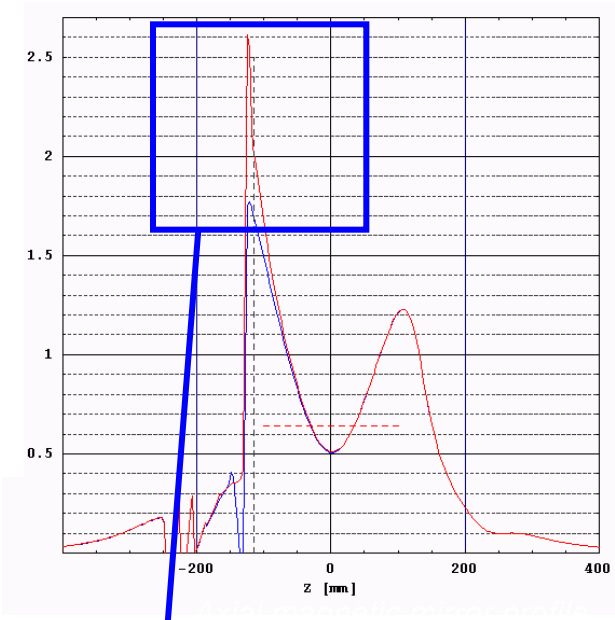
PHOENIX V2 upgrades for Spiral2

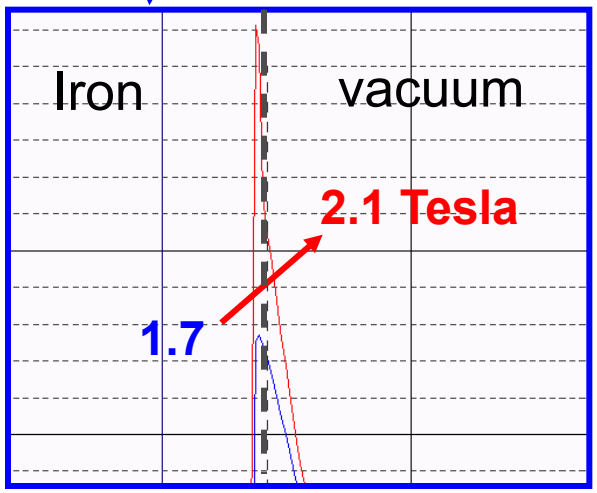
- Improvement of the axial Magnetic profile
  - 1.7 T -> 2.1 T at injection
- Improvement of the radial magnetic field
  - 1.2-> 1.35 T at chamber wall
- bias disk added
- oven access added (Ø13 mm) and Ganil LCO tested
- Aluminum alloy plasma chamber
- New 60 kV ion extraction system (triode), to be improved, currently 47 kV
- Gap : 44 mm
- Ø plasma electrode : 10 mm
- Ø extraction electrode : 18





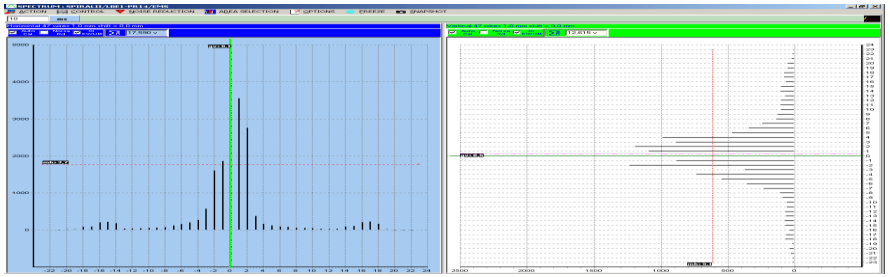
Improved injection flange (gas + oven, bias disc, RF)

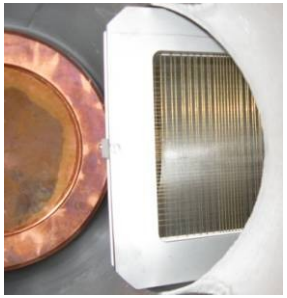




Status and Commissioning of LEBT at Grenoble

- Assembled at LPSC between June 2008 and end 2009
- First beam analyzed in may 2009
- Fully operational (2 set of slits missing)
- Commissioning started with Oxygen, Argon and Xenon (+ Calcium)
- Very good transmission : between 92 and 98 % (after optimization of optics)
- Ultra High Vacuum under beam : 2. 10^{-8} mbar in the whole line
- Extraction : 47 kV up to now (work in progress!)
- 2 Faraday Cups and 3 beam profilers tested and operational

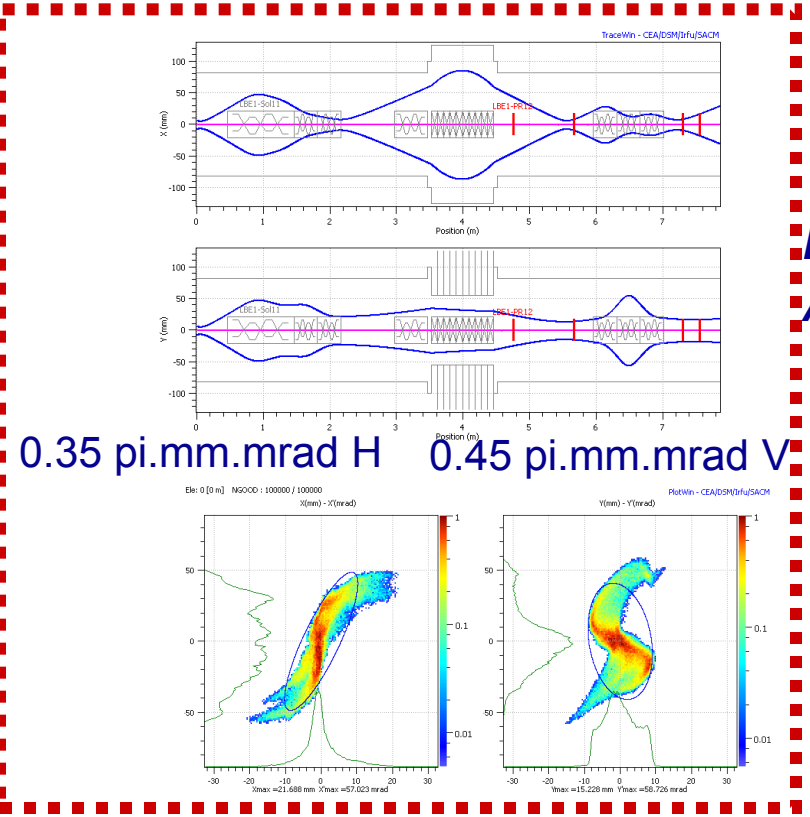




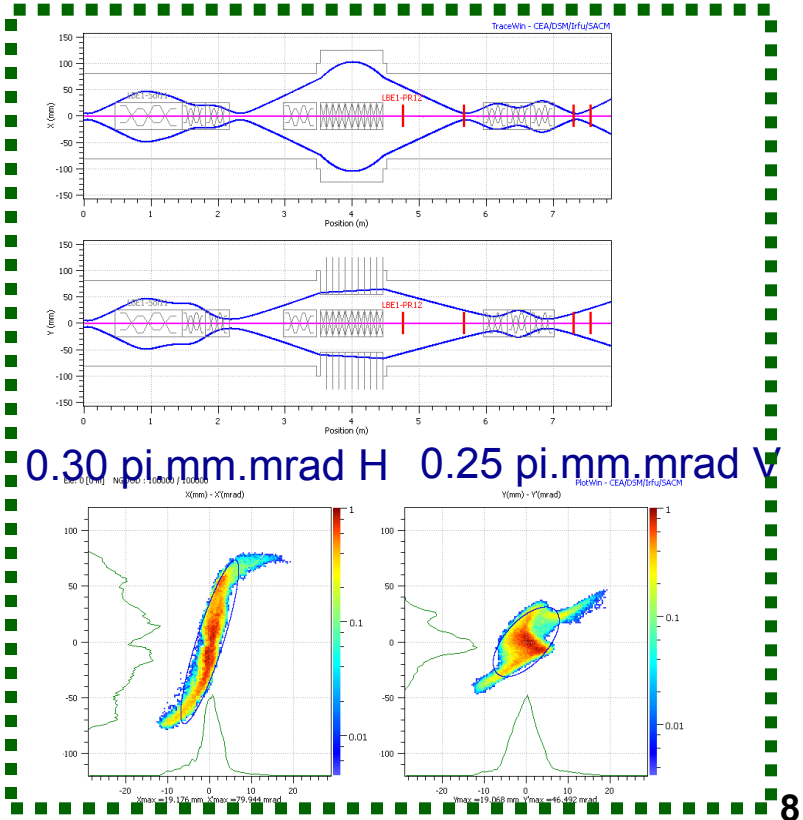
- Allison type Emittancemeters tested and results cross-checked with KVI pepper pot emittancemeter
- Control-command (EPICS) almost operational

Transport line : comparison with code simulation

- LEBT Line designed by Ganil, CEA/Irfu and IPNO with Tracewin
- Simulation was checked experimentally by measurement on different profilers and faraday cups in Argon, Oxygen and Xenon beams
- Optics was optimized with Tracewin to obtain either best current on second Faraday cup (on left) or best size on profiler (on right) :



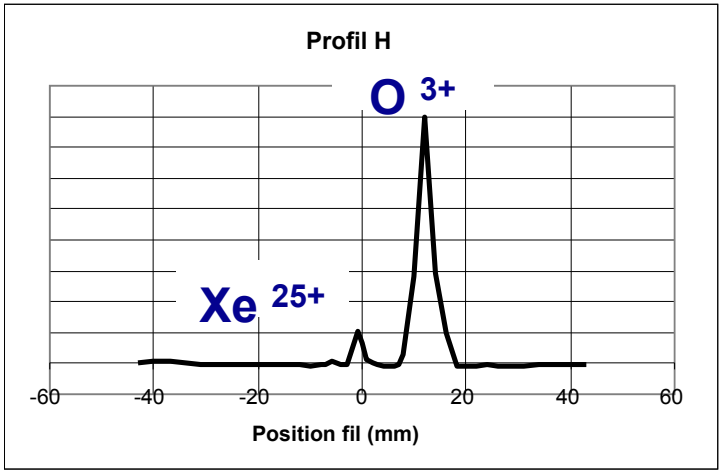
Line tuned for Ar^{12+} @40 kV

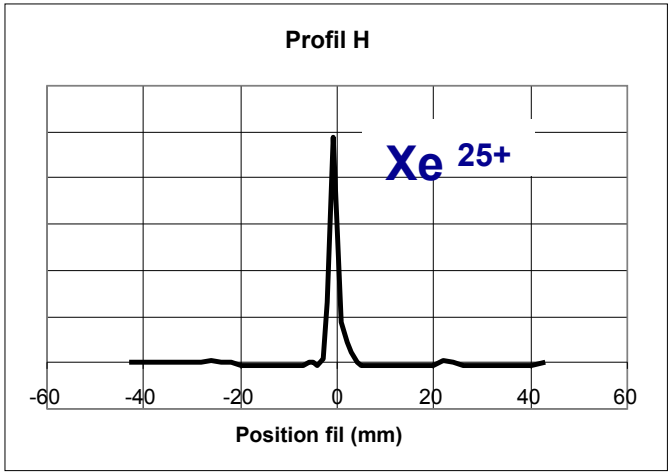


Dipole Resolving power study

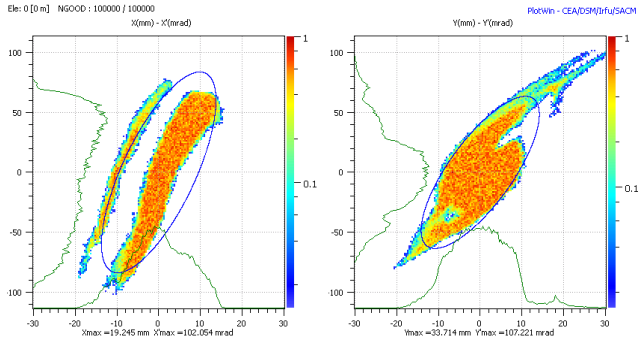
- LEBT tuned for Xenon (132) 25+ @ 40 kV
- Good separation of peaks Xe25+ and O3+ -> resolution

$$\frac{d(\frac{q}{A})}{(\frac{q}{A})} < \ \%$$

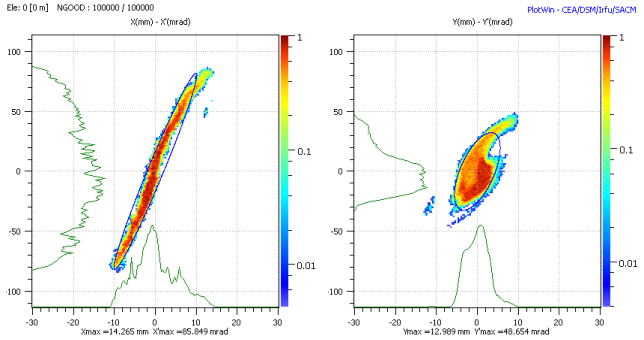




Horizontal profile with slits opened at 20mm



Horizontal profile with slits opened at 5 mm

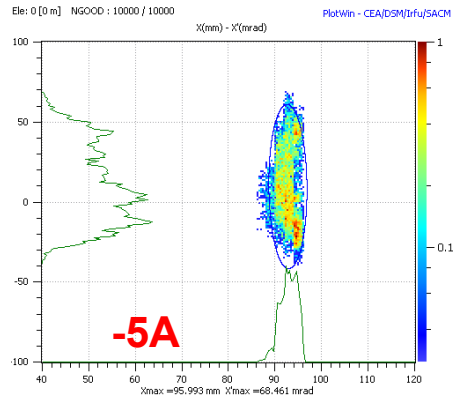


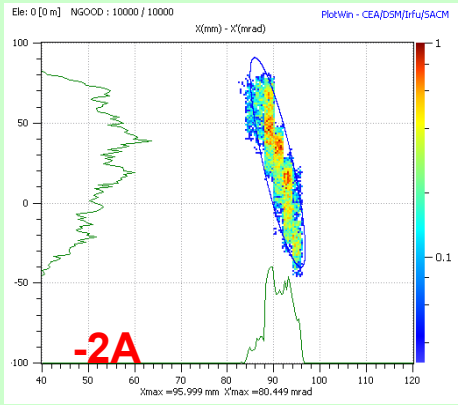
0.17 pi.mm.mrad H

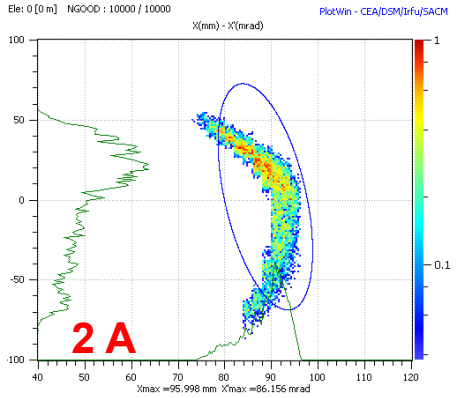
0.15 pi.mm.mrad V

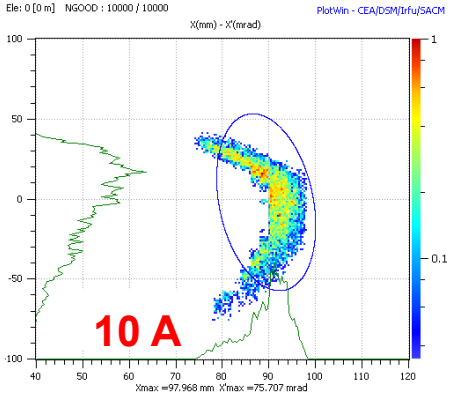
Effect of the LEBT Hexapole on the emittance

- Beam line optimized for Oxygen 6+ @ 32 kV, slits opened at 12 mm
- Horizontal emittance between 0.22 and 0.24 pi.mm.mrad rms
- Setting of the hexapole from -10 A to 10 A

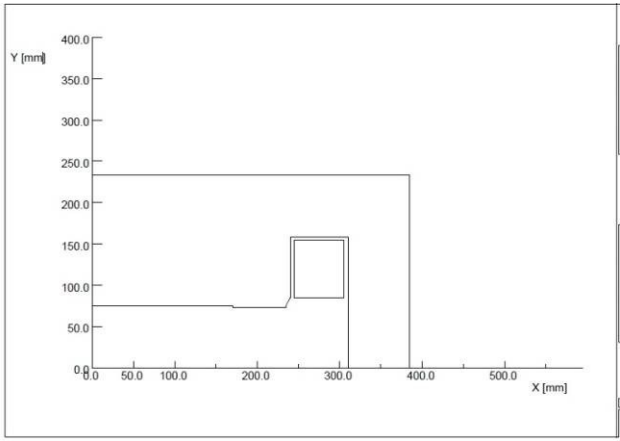








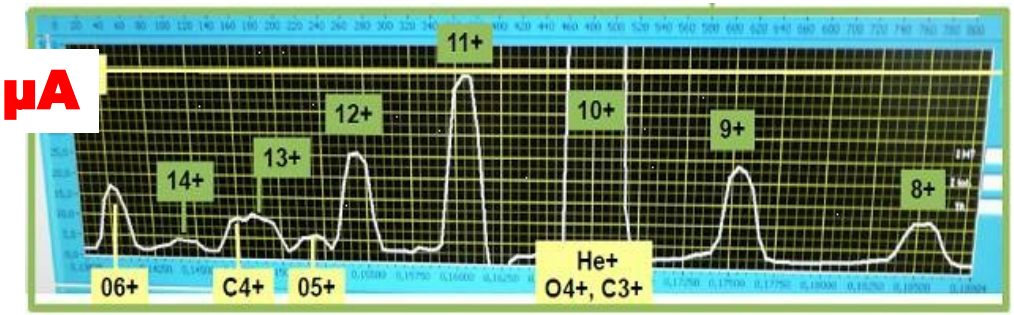
Hexapole allows the second order aberrations compensation created by the bending magnet (designed with simple flat shimmed poles)



First Ganil LCO oven test on LEBT

- Collaboration with GPI Ganil
- Large Capacity Oven
- Max Temperature : around 1500 °C under beam
- Ø outer : 10 mm
- Tungsten filament Ø 0.3 mm
- Container Al203 Ø inner : 4.4 mm
  length : 27 mm
- First beam on July 2010 with Calcium 40, 400 W @ 20 kV
  with Phoenix V2

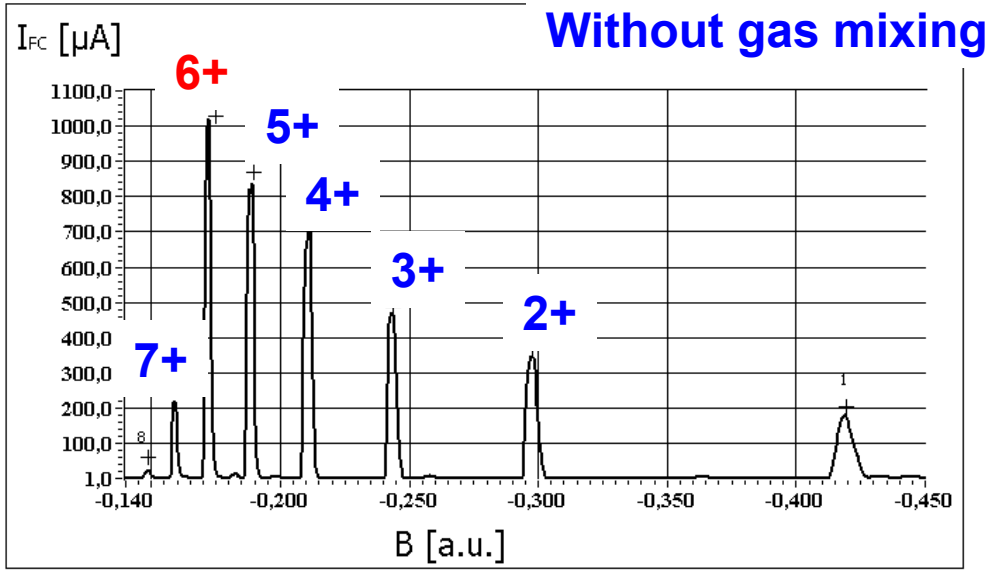
I Ca11+ = 100 µA

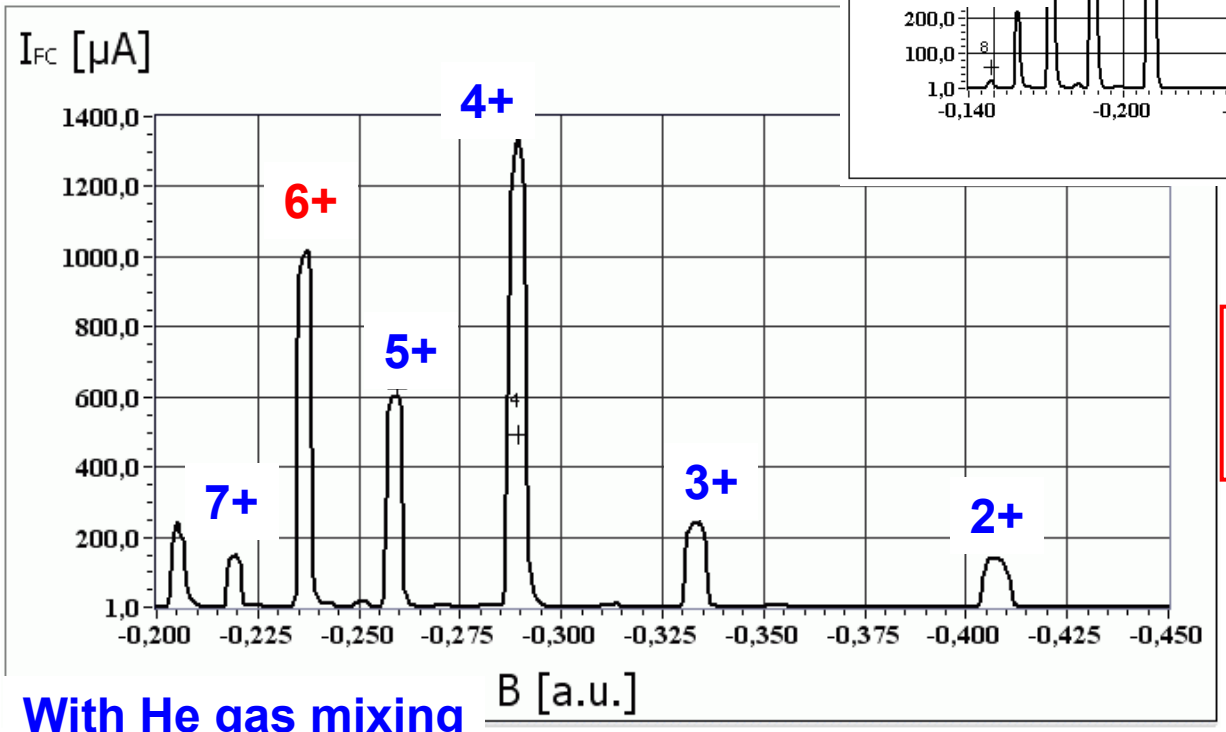


- Not optimized beam, only to check the good working of the oven and to study the effect of self microwave heating of the oven

First results with Oxygen beams

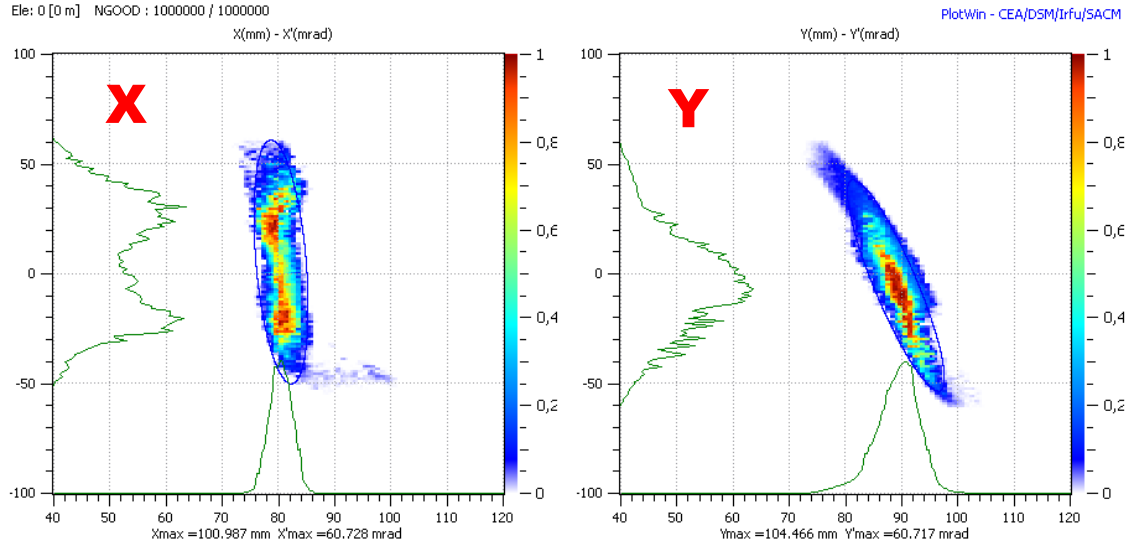
- 1 kW, 45 kV, I tot on CF11 : 4 mA
- Transmission : 95 %
- I Oxygen 6+ : 1,05 mA
- Phoenix V2 very easy to tune
- Reproducible and stable !
- Milestone fulfilled





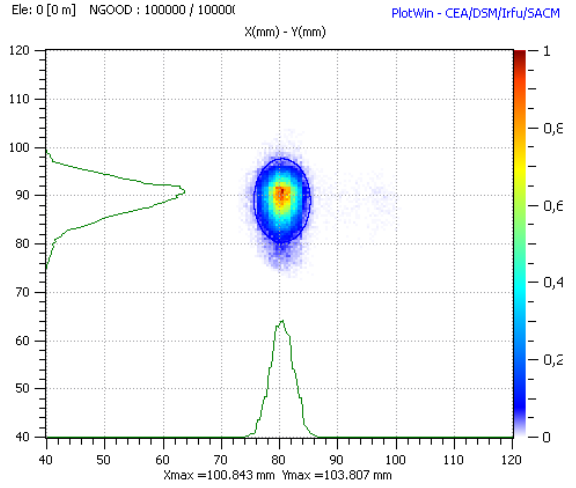
Phoenix V2 not optimized above 1 kW
Results can be improved !

Oxygen beams : emittances and profiles



0.30 pi.mm.mrad

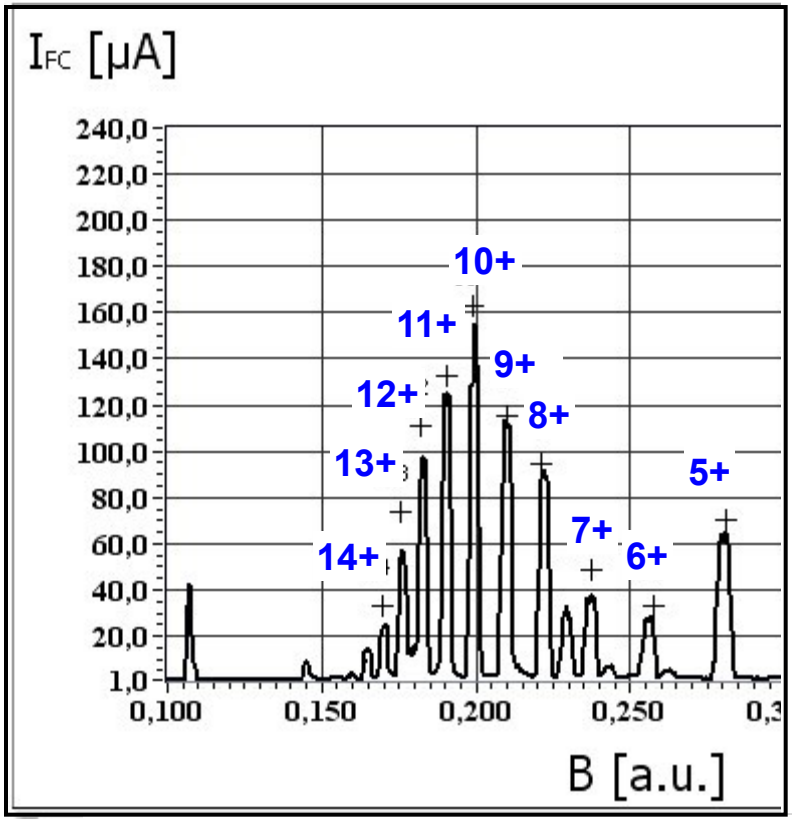
0.24 pi.mm.mrad



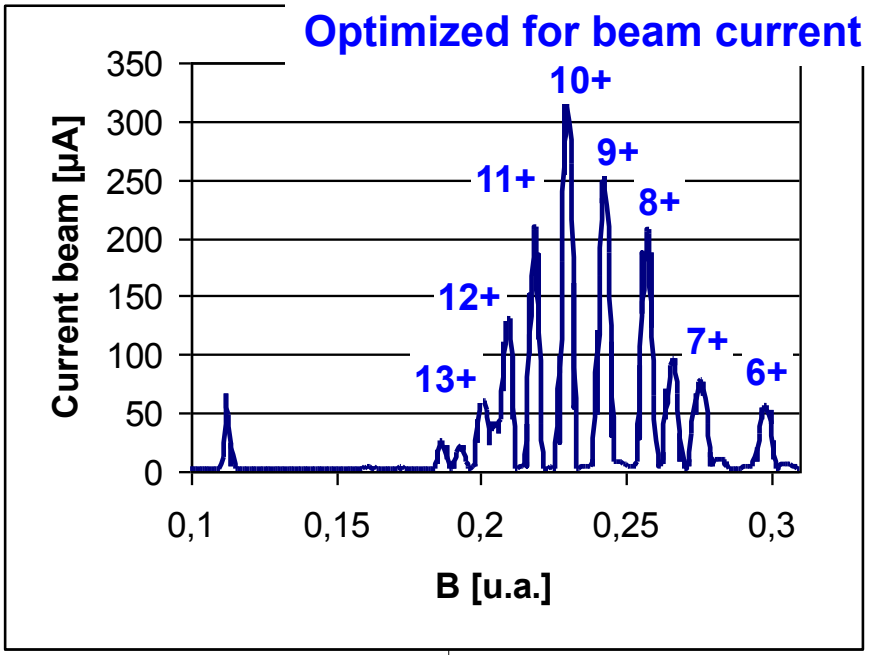
- Profile of Oxygen 6+, 800 µA
- 45 kV, 1 kW,
- Circular beam
- Emittance grows with current beam
- < 0.4 pi.mm.mrad
- Milestone fulfilled

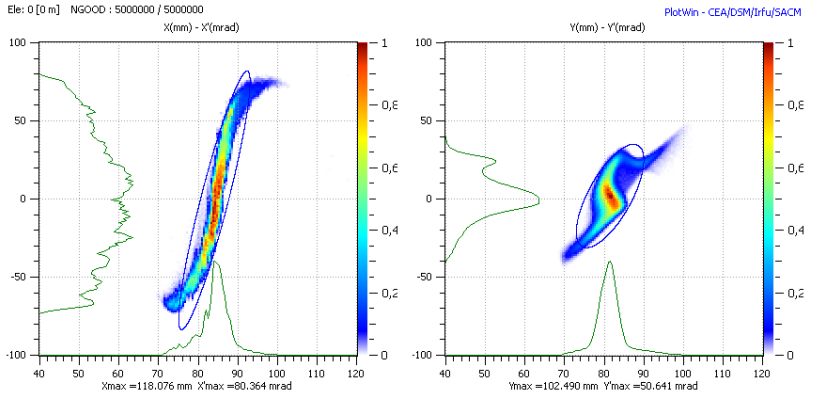
First results with Argon beams

- Profile of Argon 12+, max 130 µA
- 40 kV, 900 W, high voltage and RF power not fully optimized, to be increased gradually



Optimized for higher charge state

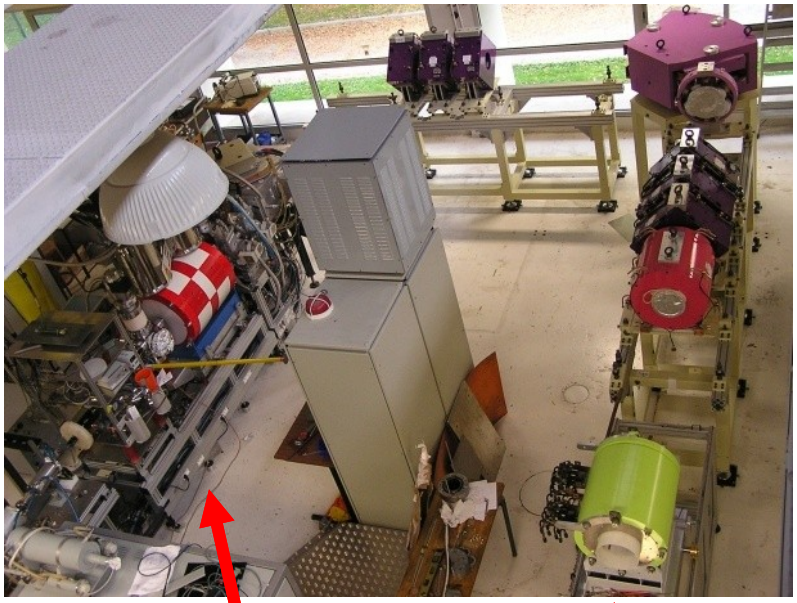




0.30 pi.mm.mrad *0.25 pi.mm.mrad*

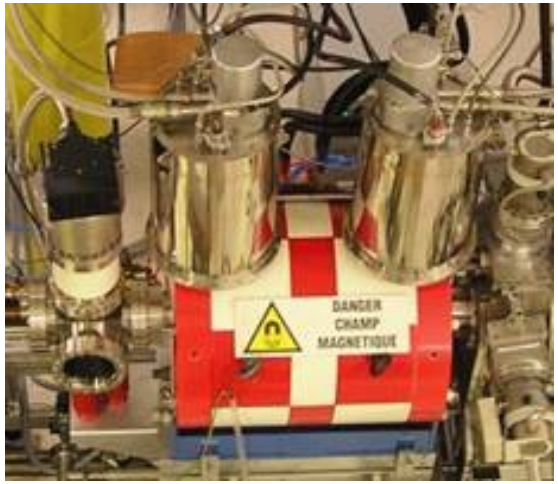
Status of A-PHOENIX commissioning @ 18 GHz

- A-PHOENIX bench in front of the LEBT
- A-PHOENIX stopped in 2010 to allow commissioning of LEBT with PHOENIX V2



A-PHOENIX Bench

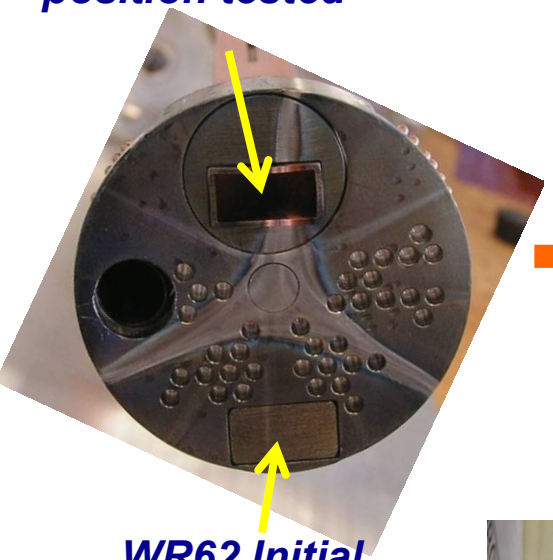
LEBT



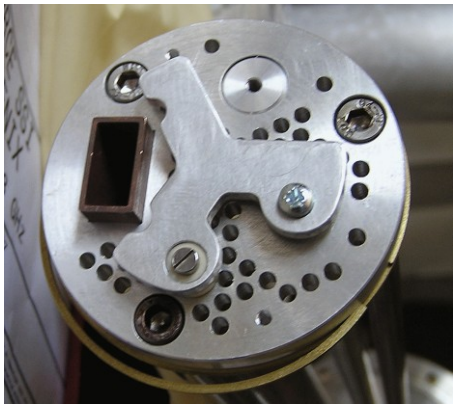
Status of A-PHOENIX commissioning @ 18 GHz

- **Autumn 2009: HF radius injection study**
  - HF radius moved from R (plasma wall) to R/2 of plasma chamber.
  - Best HF coupling, first high charge state production observed (Ar16+ visible for 1st time)
    - ☞ HF radius of injection is one of the main issue of the source
- **Design of a new injection with R_{HF}~R/2**
  - With a welded below system to move injection flange
  - Construction now finished
  - To be tested soon

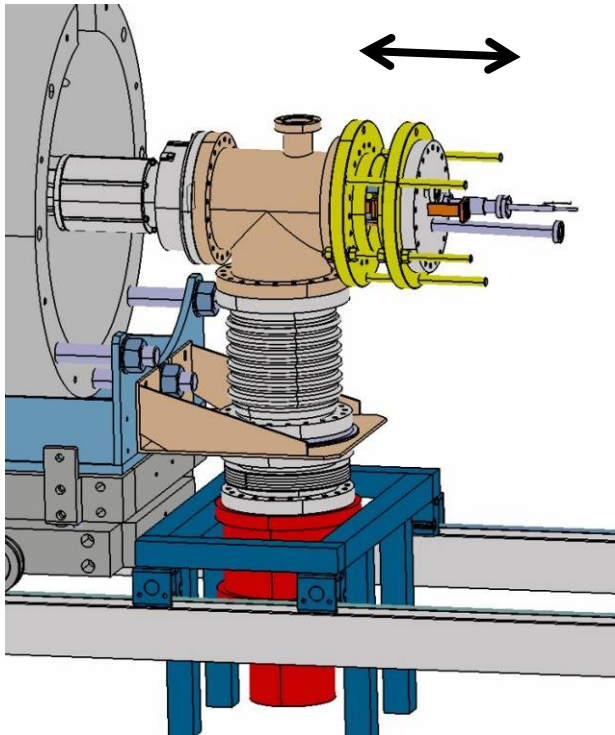
WR62 new position tested



WR62 Initial position (filled up)

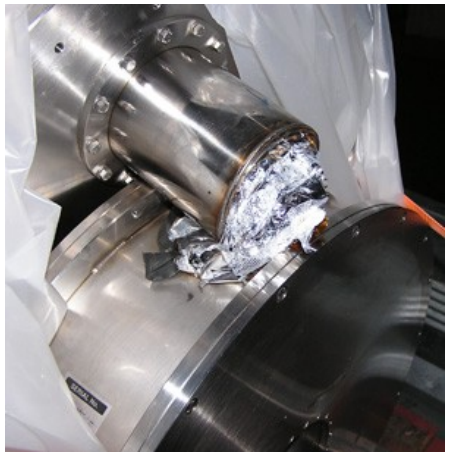


New Modified design

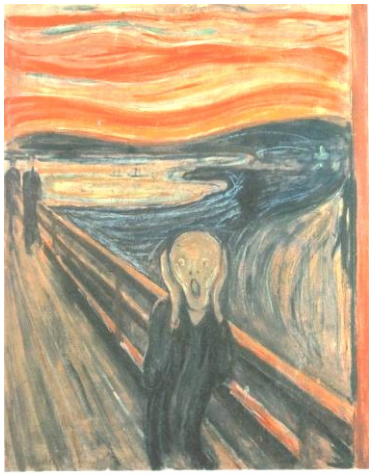


A-PHOENIX Cryostat break

- Experiments stopped in december 2009 because of an air leak in one HTS cryostat
- During unmonting for repairing, the cryostat broke into two parts!!!
  - Total Failure of a weld in the cryostat neck
  - Due to insufficient weld from Scientific Magnetic
  - Fast aging of the weak weld due to the cryocooler vibrations



Cryostat weld broken…



Cryostat back after repair

- Scientific Magnetic successfully repaired the cryostat and reinforced the weld.
  - No damage of superconducting parts!
- HTS coil reached again its nominal T° and current in July 2010.

Prospects

- Increase RF power (2 kW) and High voltage extraction (60 kV) to get nearer to Spiral 2 specifications
- Continue beam tests especially metallic ion beams
- Restart up A-Phoenix commissioning with its new injection
- Move A-Phoenix on the LEBT