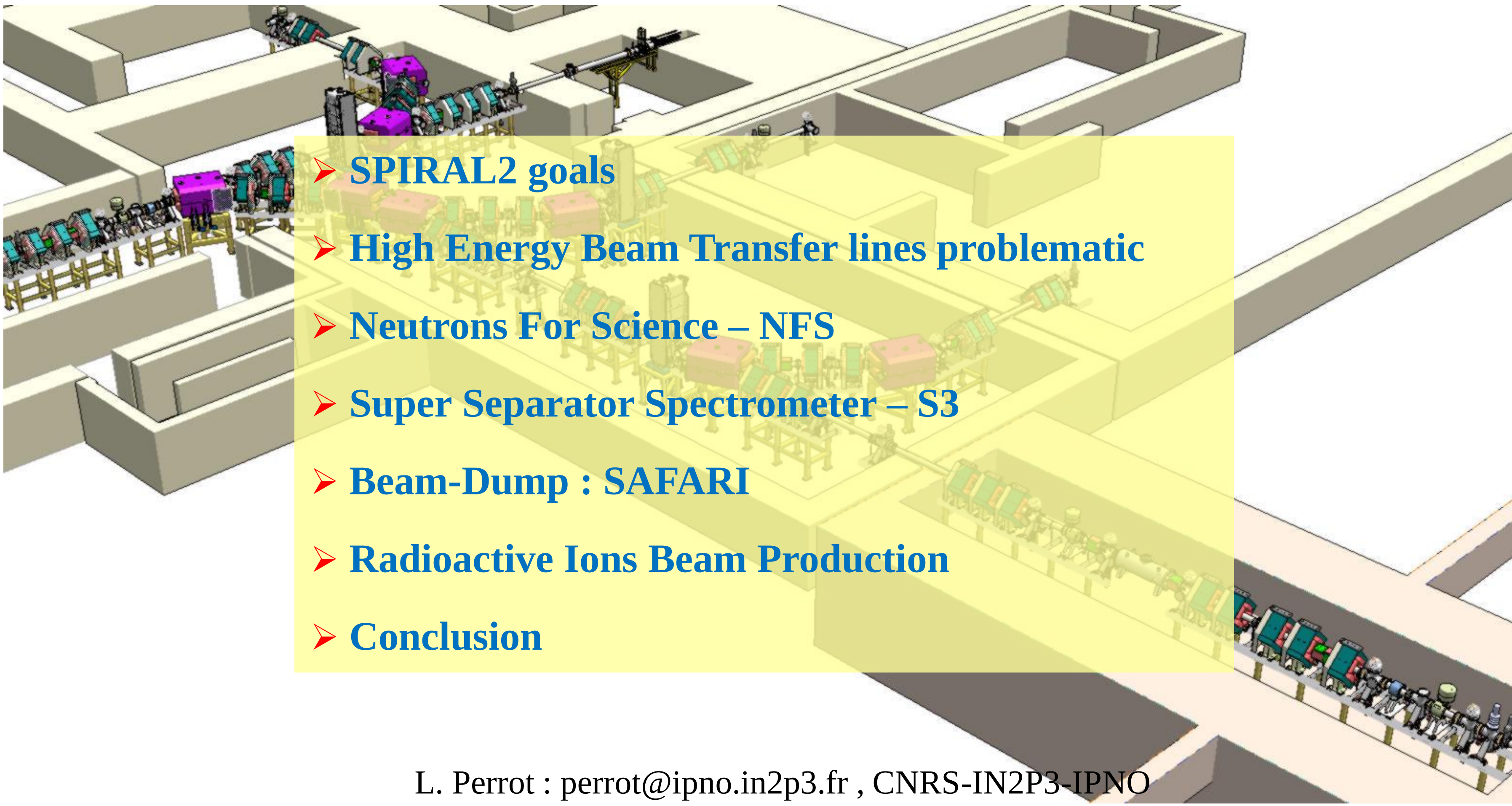
HEBT lines for the SPIRAL2 facility. What to do with accelerated beams ?



- SPIRAL2 goals
- High Energy Beam Transfer lines problematic
- Neutrons For Science – NFS
- Super Separator Spectrometer – S3
- Beam-Dump : SAFARI
- Radioactive Ions Beam Production
- Conclusion

L. Perrot : perrot@ipno.in2p3.fr , CNRS-IN2P3-IPNO

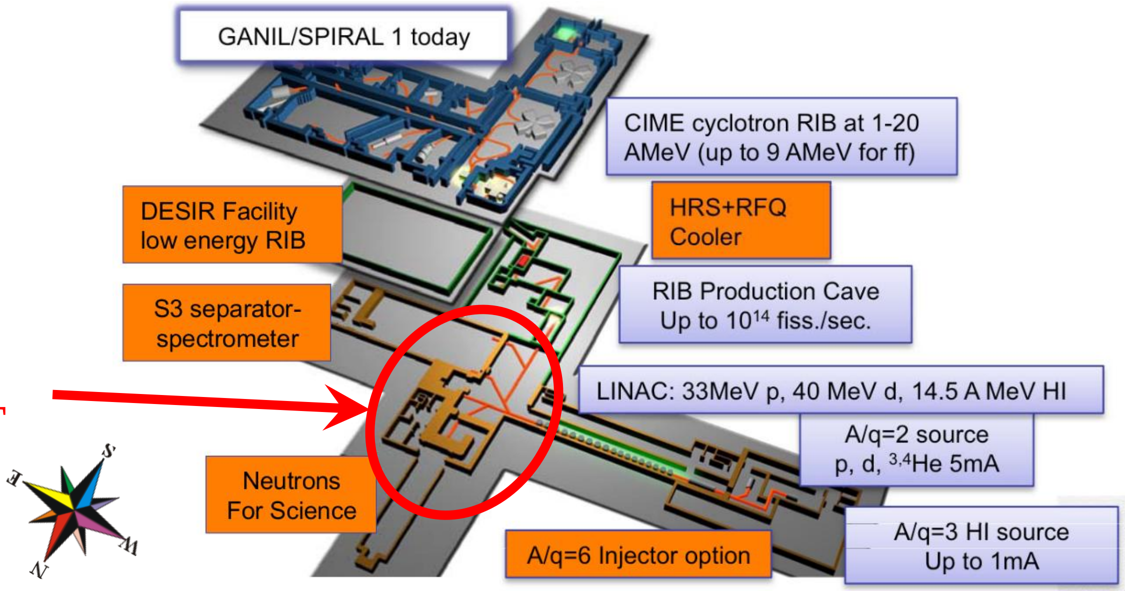
SPIRAL2 goals

- Strong demand on Radioactive Ions Beams by the nuclear physics community
- Fundamental knowledge of the atomic nuclei
- Interdisciplinary research : ions-ions collisions, neutrons XS, material irradiations using neutrons

Extend the actual possibilities given by GANIL at Caen

- RI produced by fission process, fusion evaporation residues or transfer products
- High intensity stable primary beams : P, D, ^{3,4}He, heavy ions with A/Q=3 (1mA-5mA)
- Energy range : from 2MeV/u up to 20MeV/u (D), 14.5MeV/u (HI), 33MeV (P)

Area of the talk : HEBT



- **2 ECR sources**
- **2 LEBT**
- **1 RFQ 88.05 MHz**
- **LINAC (cavities : β=0.07 and 0.12)**
- **HEBT : 90m**
- **-9.5m underground**

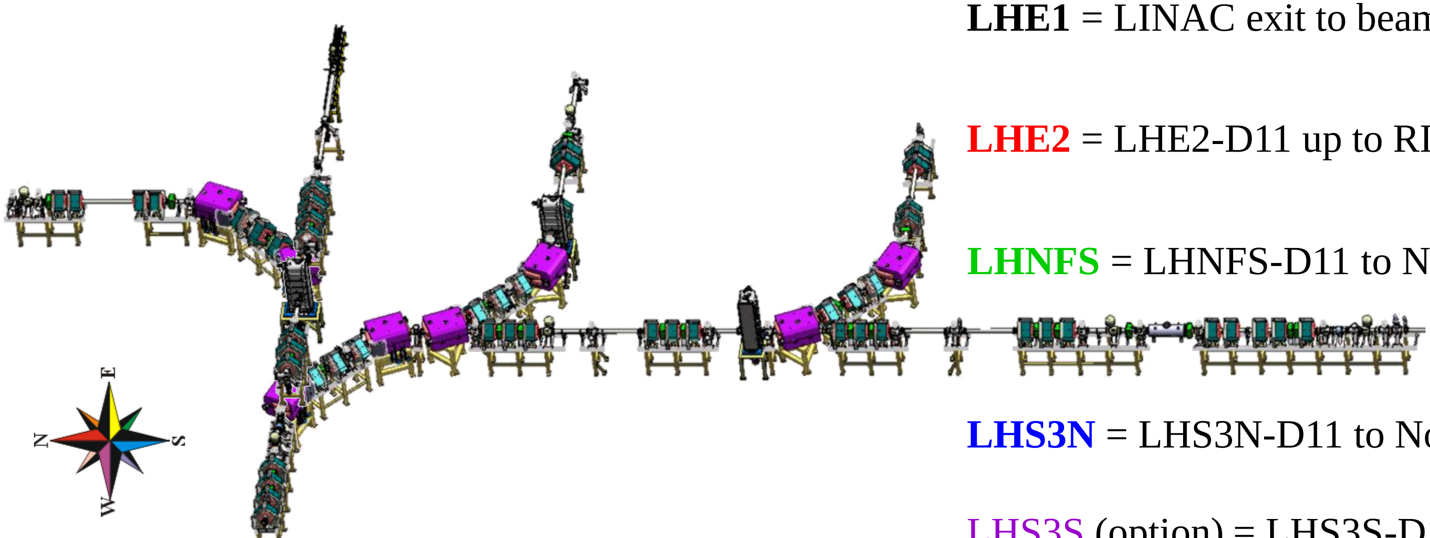
High Energy Beam Transport lines

- HEBT must be able to transport large range of species at various energies
- Beam losses have to be minimized: <1 W/m

Deuterons : 4MeV – 40MeV, 5mA
Protons : 2MeV – 33MeV, 5mA
Ions A/Q=3 : 2-14.5MeV/u, 1mA $^{18}O^{6+}$,$^{48}Ca^{16+}$
Upgrade : A/Q=6 : up to 8.5MeV/u

} 0.2Tm<Bρ<2.52Tm

Constraints : Sizes of the quad, dipoles, i.e. available place.
Current alimentation stability specifications. Diagnostics working range.



LINAC

LHE1 = LINAC exit to beam-dump

LHE2 = LHE2-D11 up to RIB converter (production)

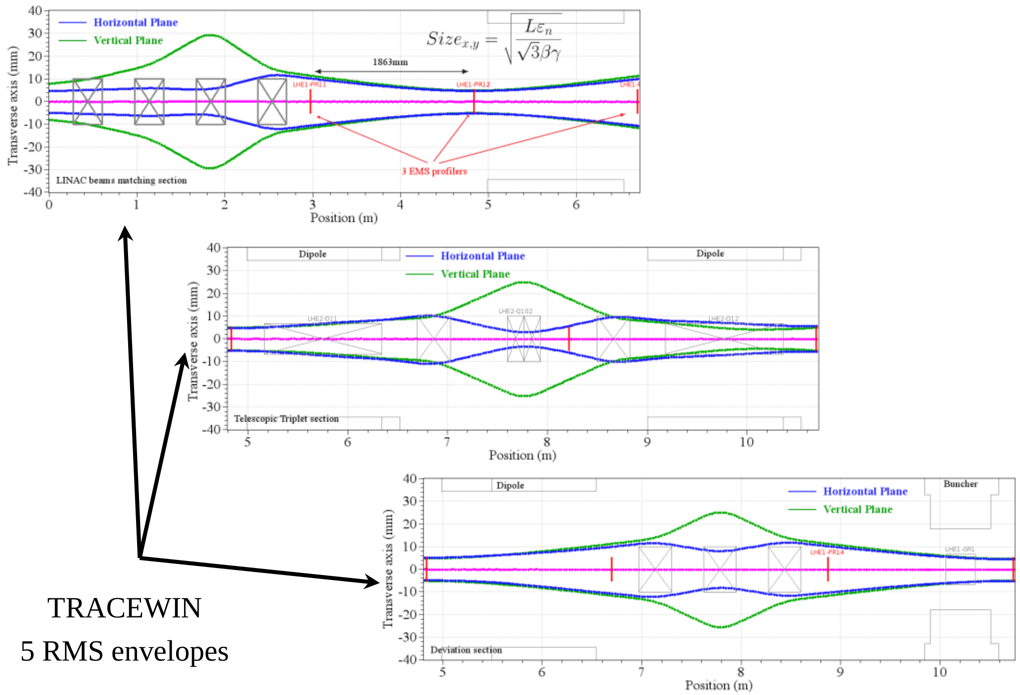
LHNFS = LHNFS-D11 to NFS exp. area

LHS3N = LHS3N-D11 to North S3 exp. area

LHS3S (option) = LHS3S-D11 to South S3 exp. Area

High Energy Beam Transport lines

- Simple & robust : use repeated structure (matching and triplet section, section, 90° deviation)
  - 5 Matching sections composed of 4 quadrupoles are used at the LINAC exit, for the beam dump, and at the entrance of each experimental room,
  - 5 Triplet sections : repetitive transverse waists and periodic envelopes
  - Achromatic double deviations : beam distribution and protection of targets against energy fluctuations
- Beam transport must be reproducible : clear beam tuning and control procedure
- Easy to tune : transverse profiles, energy measurement (ToF), residual gas ionization monitor, time pulse length measurement …
- Safe : Loss rings along the lines, beam currents, BLM, segmented collimator in front of beam-dump, Dipole works as security equipment



TRACEWIN
5 RMS envelopes

- 49 Quad : ϕ=128mm, L_m=300mm (G_{max}=10T/m & 13T/m)
- 8 dipoles : 45°, ρ=1.5m, gap=80mm, B_{max}=1.68T, P=56kW.
- 3 buncher cavities β=0.07
- 12 X & Y steerers
- 27 EMS profilers
- Energy measurement: ToF tech., diamond like detector
- Beam current measurements
- 4 BPM, 11 BLM
- 12 loss rings

Neutrons For Science

New experimental area dedicated to :

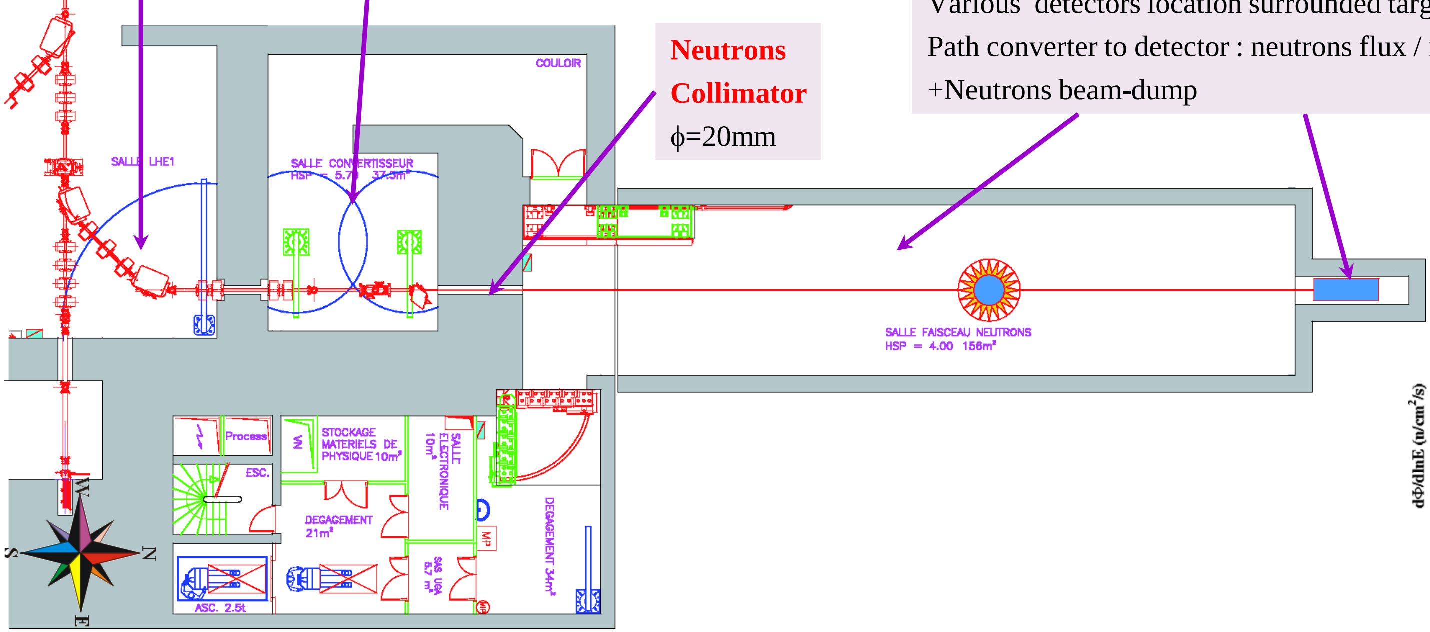
- Fission process, nuclear waste transmutation : use the n-ToF technique
- XS measurements by activation technique
- Atomic physics : material under irradiation, damage

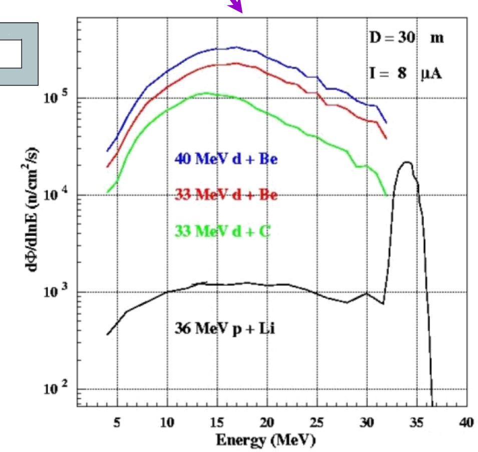
HEBT-NFS
Beam : D, P, He, C
Imax=50µA, P=2kW

Converter room : 6m long
Need to a versatile targets chamber
Targets : Be, C, Li, Al, Fe, Cu, SiC, ZrO_2
+Dipole for Proton beam rejection
+ Beam stop

Neutrons Collimator
ϕ=20mm

Neutrons Time of Flight room : 25m long
Various detectors location surrounded targets like actinides (Pu, Cm …)
Path converter to detector : neutrons flux / neutrons resolution
+Neutrons beam-dump

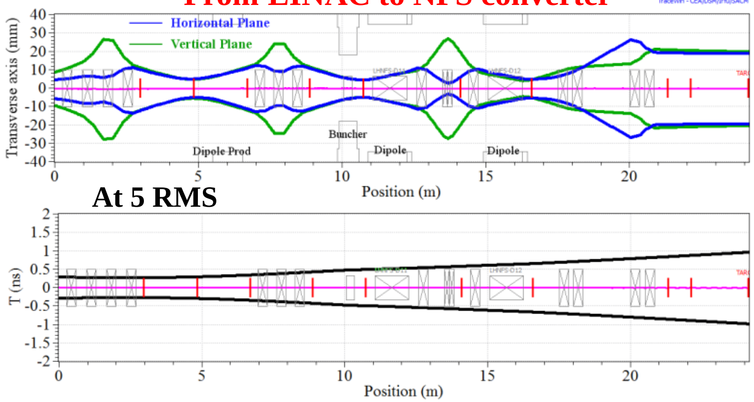




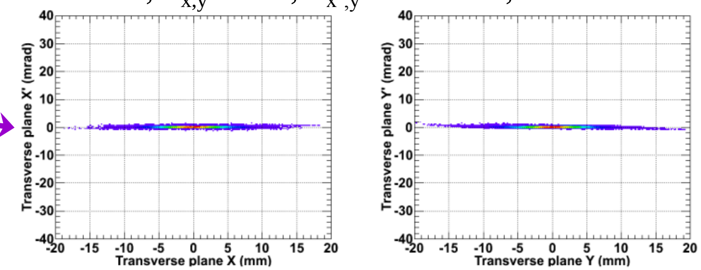
Neutrons For Science

Beam Dynamics for NFS : the case of 33MeV Protons

From LINAC to NFS converter



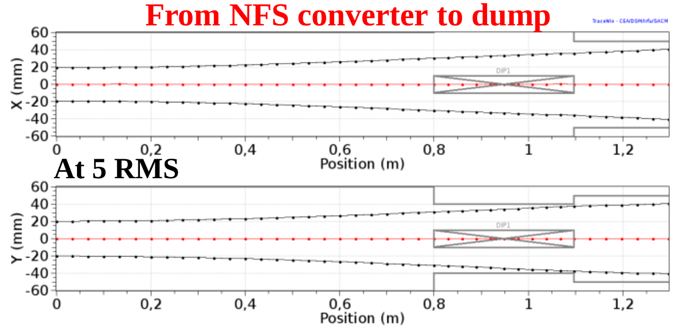
P : 33MeV, $\sigma_{x,y}$~4mm, $\sigma_{x',y'}$~0.25mrad, ε~1πmm.mrad



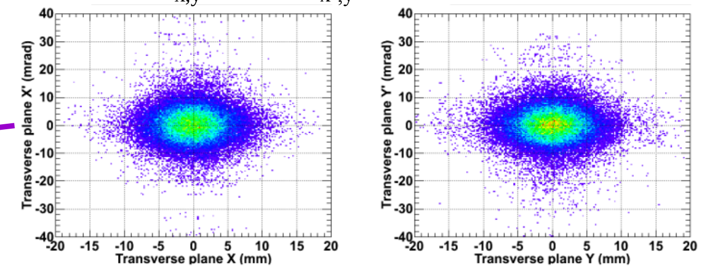
At NFS :

- Thick targets : beam normally stop inside
- Thin Lithium targets for mono-energetic neutrons, beam is slow-down

From NFS converter to dump

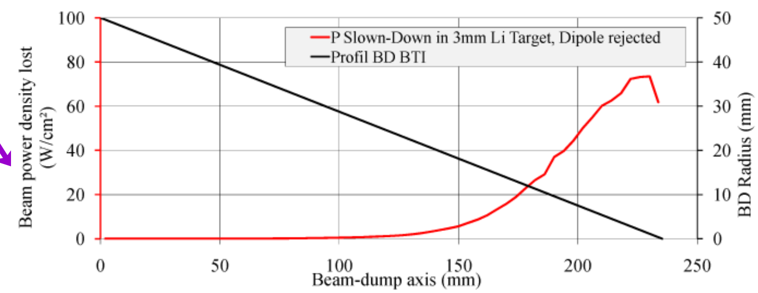


P : 30.8MeV, $\sigma_{x,y}$~4mm, $\sigma_{x',y'}$~5.8mrad, ε~23.2πmm.mrad



Slow-down P beam must be rejected and stopped (dipole + dump)

Dipole : θ=17°, ρ=1m, gap=80mm, $B\rho_{max}$=1.3T



NFS Beam-dump : use the already designed BD of SP2 LME

Φ=100mm, open angle=12°

Super Separator Spectrometer

A new experimental area dedicated to :

- Super-heavy & very-heavy nuclei : Z > 100
- Spectroscopy at and beyond the drip-line
- Isomers and ground state properties
- Multi-nucleon transfer and deep inelastic reactions

Requiring the separation of very rare event from intense backgrounds : S3

HEBT-S3

Beams : A/Q=3, ^{18}O, ^{48}Ca, ^{58}Ni, ^{12}C, ^{86}Kr

Imax=1mA

E : 2MeV/u – 14.5MeV/u

S3 targets

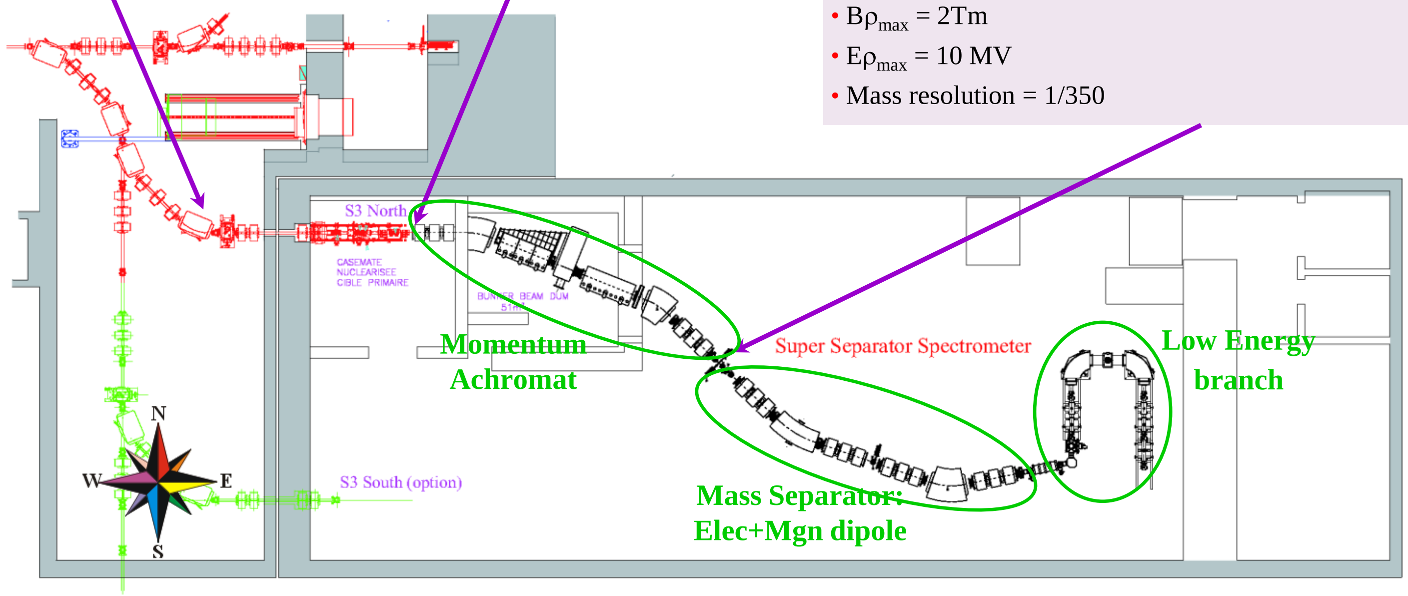
U, Am, Cm, Ti

Rotating system

+ beam sweeper

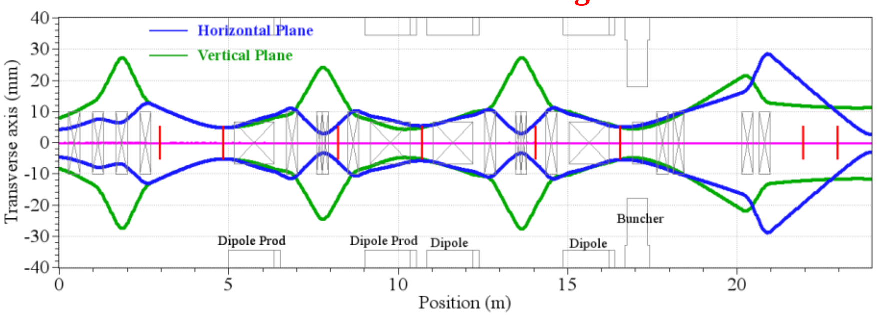
A Challenging Separator + Spectrometer. Based on J. Nolen design

- Angular acceptance: +/- 80 mrad X and Y
- Br acceptance: +/- 10%
- Primary beam rejection : 10^{13}
- $B\rho_{max}$ = 2Tm
- $E\rho_{max}$ = 10 MV
- Mass resolution = 1/350



Super Separator Spectrometer

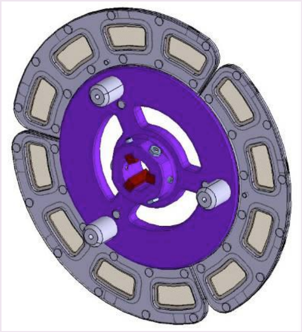
From LINAC to S3 target



High Power Target Stations

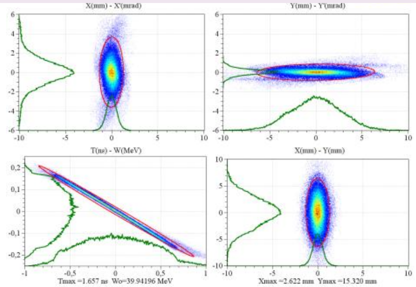
2 rotating targets types are studies :

- Stables : ^{208}Pb, ^{209}Bi, Ni, Ca, C
  with Radius = 25cm
- Actinides : ^{232}Th, ^{238}U, $^{239-242-244}$Pu, ^{248}Cm
  with Radius=6-15cm



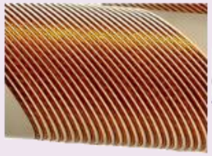
Beam size on target :

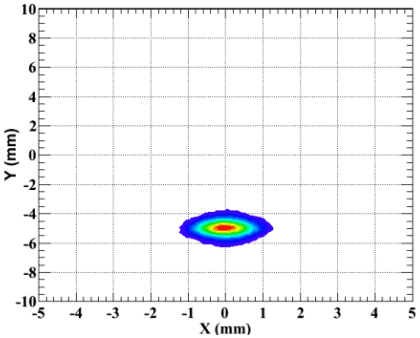
RMS X=0.5mm, RMS Y: from 0.5 up to 2.5mm

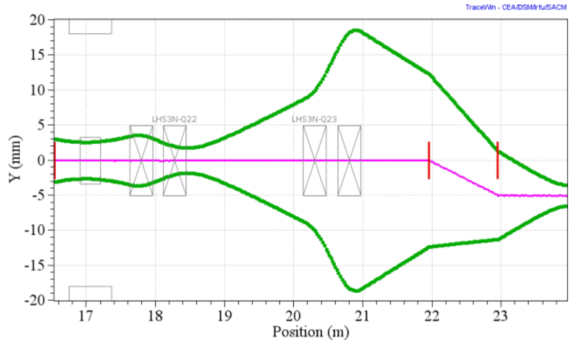


The beam power density deposed in target required in some case to use a beam sweeper installed in the last section of the HEBT

The system can be based on the system designed by **Advanced Magnet Lab :**
"Direct Double Helix™" , http://www.magnetlab.com/technology/direct-double-helix/





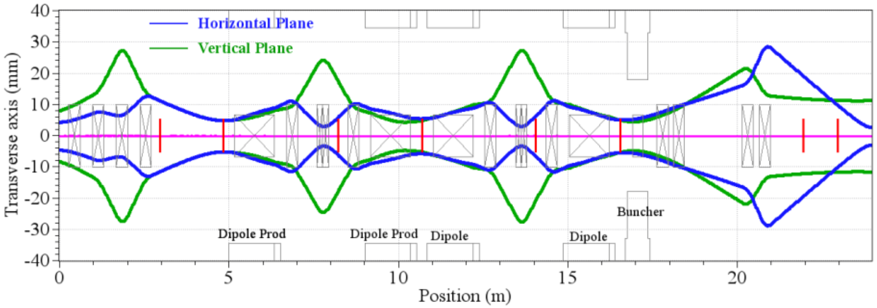


Need to have

B_{max} < 1kG, f~kHz with DDH

Super Separator Spectrometer

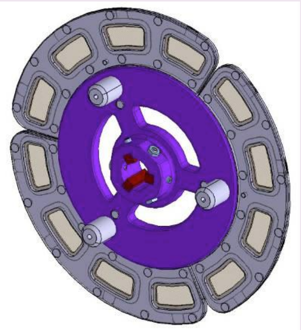
From LINAC to S3 target



High Power Target Stations

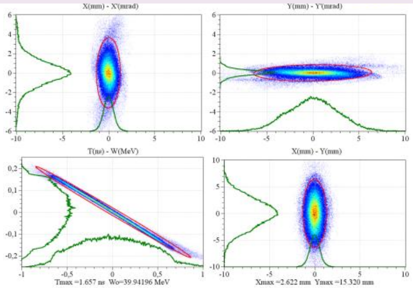
2 rotating targets types are studies :

- Stables : ^{208}Pb, ^{209}Bi, Ni, Ca, C
  with Radius = 25cm
- Actinides : ^{232}Th, ^{238}U, $^{239\text{-}242\text{-}244}$Pu, ^{248}Cm
  with Radius=6-15cm



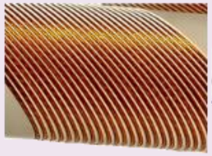
Beam size on target :

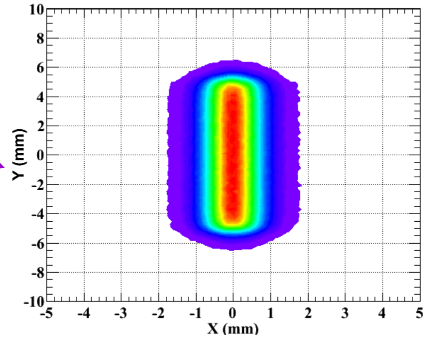
RMS X=0.5mm, RMS Y: from 0.5 up to 2.5mm

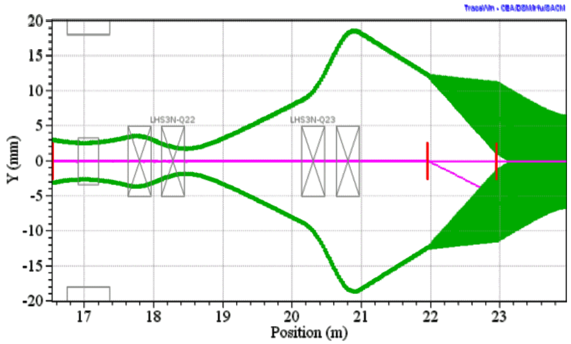


The beam power density deposed in target required in some case to use a beam sweeper installed in the last section of the HEBT

The system can be based on the system designed by **Advanced Magnet Lab :** **"Direct Double Helix™"** , http://www.magnetlab.com/technology/direct-double-helix/







Need to have

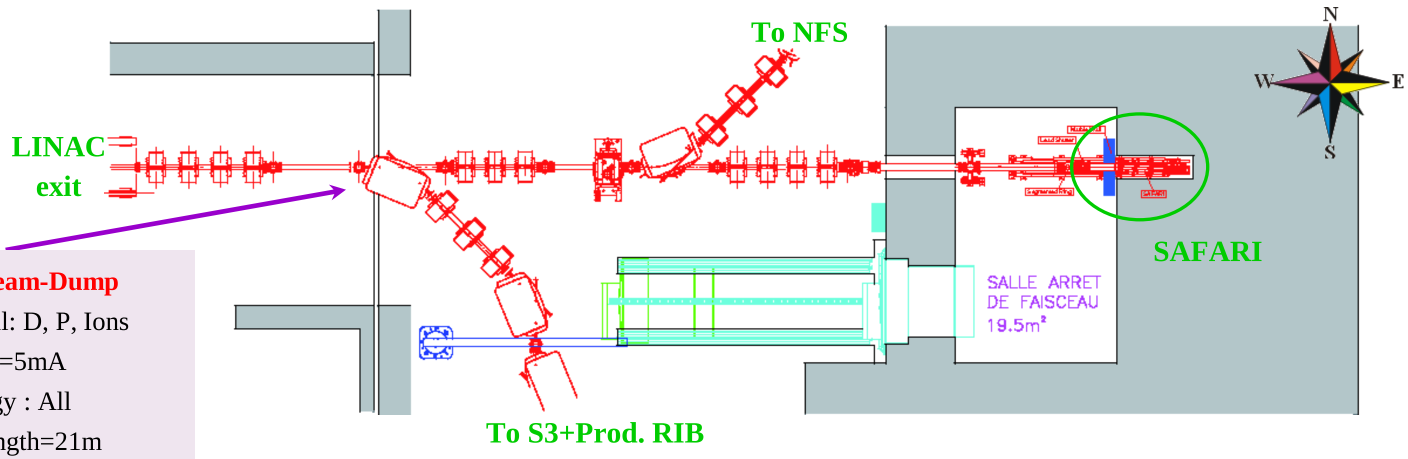
B_{max} < 1kG, f~kHz with DDH

Beam-Dump : SAFARI

SAFARI : Système d'arrêt Faisceau Adapté aux Rayons Intenses (in French)

Optimized Beam Stop Device for High Intensity Beams

- Accelerator facility commissioning
- Beam tuning along the accelerator
- Beam qualifications and controls during run



HEBT-Beam-Dump

Beams : All: D, P, Ions

Imax=5mA

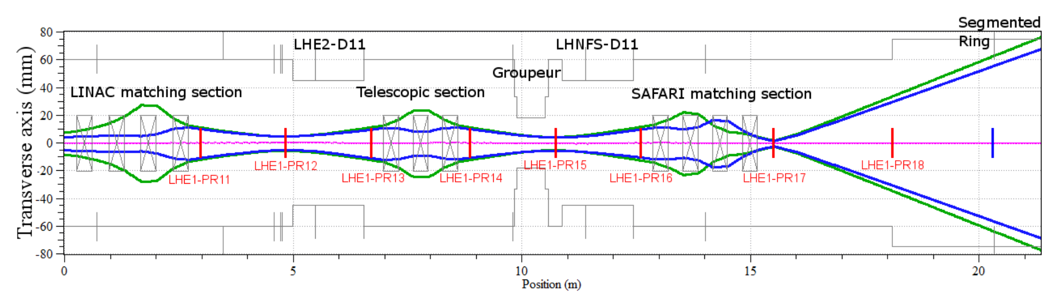
Energy : All

Line Length=21m

Must be able to stop a Deuterons beam at 40MeV and 5mA (200kW)

For safety aspects :

- Limitations is 10kW during 1 hour / day for a 3 months run
- A separated cave for the device, restricted area. No access in normal operation

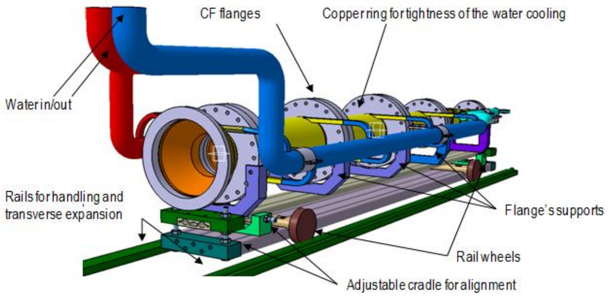


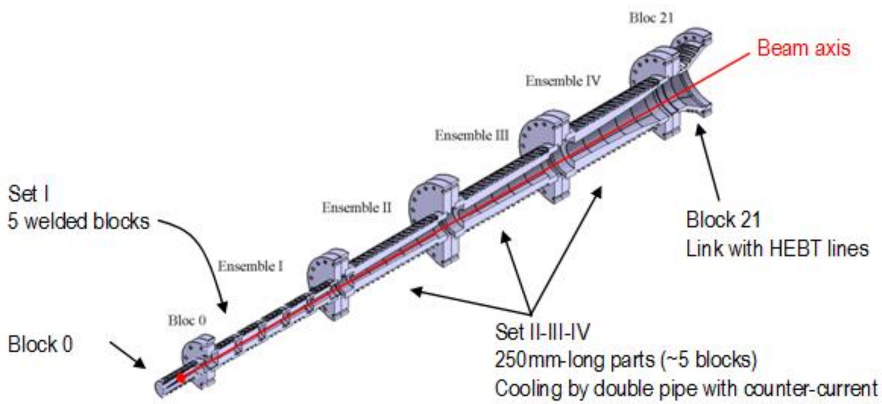
All beam type matched in order to have a RMSx,y~16mm at the beam-dump entrance

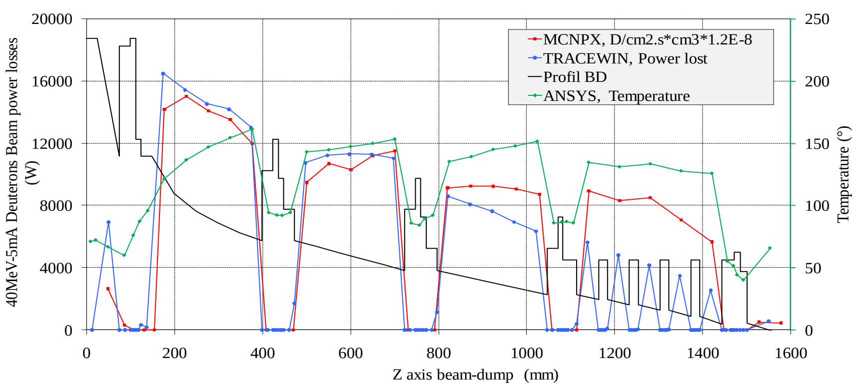
Beam-Dump : SAFARI

Work done in SPIRAL2PP collaboration with CIEMAT & UNED Madrid, CNRS-IPN Orsay and Lyon (E. Schibler task leader)

- Beam dynamic: IPNO, L. Perrot
- Thermo-mechanic, integration: IPNL, E. Schibler
- Safety : UNED Madrid, A. Mayoral
- Monitoring achievement of prototype : CIEMAT







Assembling :

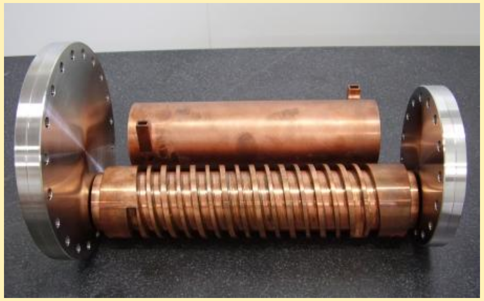
- ConFlat flanges in stainless steel, welded on the Copper blocs
- Set I : 5 welded Copper blocs (too thin internal radius)
- Quick collar flange for bloc 21

Cooling :

- Water circulation in channels directly machined
- Single (bloc 0, 21, Set I) and double (Set II, III, IV) spiral channels

See details in E. Schibler proceeding to LINAC10

Set II Prototype by TRINOS (Valencia).



- Errors studies have been done: mismatching & misalignments
- SAFARI is dimensioned to resist to RMS 6.6mm over focused beam
- Radioprotection : at 20cm after 1day, dose rate is 20mS/h

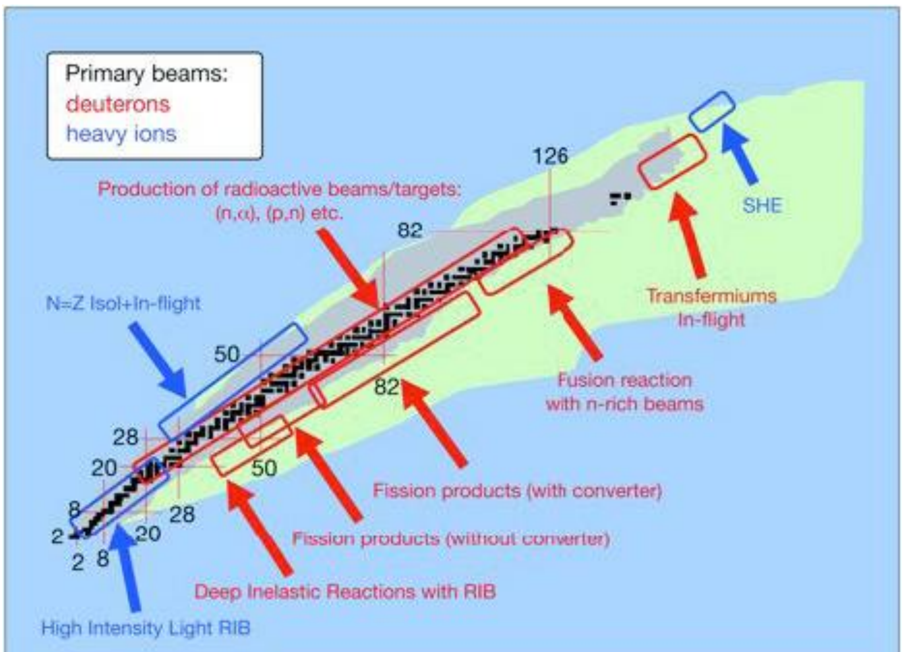
RIB PRODUCTION

Radioactive Ions Beams : Production to new isotopes

- To Perform experiments on a wide range of rich Nuclei far from the line of stability
- Different production mechanisms and techniques to create the beams

Target R&D and RIB production module is particularly challenging

- Objective is to have a UCx target which will be able to receive the 200kW Deuterons Beam
- Fission rate inside target expected : 10^{14} fission/s
- Produced Nuclei : 60<A<140, rate : from 10^{6} up to 10^{11} pps



RIB PRODUCTION

Radioactive Ions Beams : Production to new isotopes

- To Perform experiments on a wide range of rich Nuclei far from the line of stability
- Different production mechanisms and techniques to create the beams

Target R&D and RIB production module is particularly challenging

- Objective is to have a UCx target which will be able to receive the 200kW Deuterons Beam
- Fission rate inside target expected : 10^{14} fission/s
- Produced Nuclei : 60<A<140, rate : from 10^{6} up to 10^{11} pps

HEBT-Prod RIB

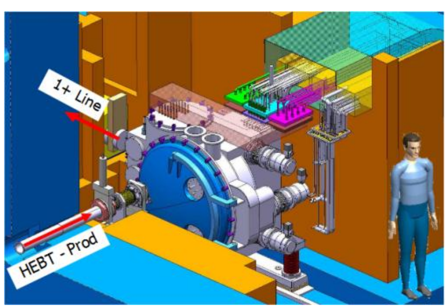
Beams : D, light ions $^{3,4}He$

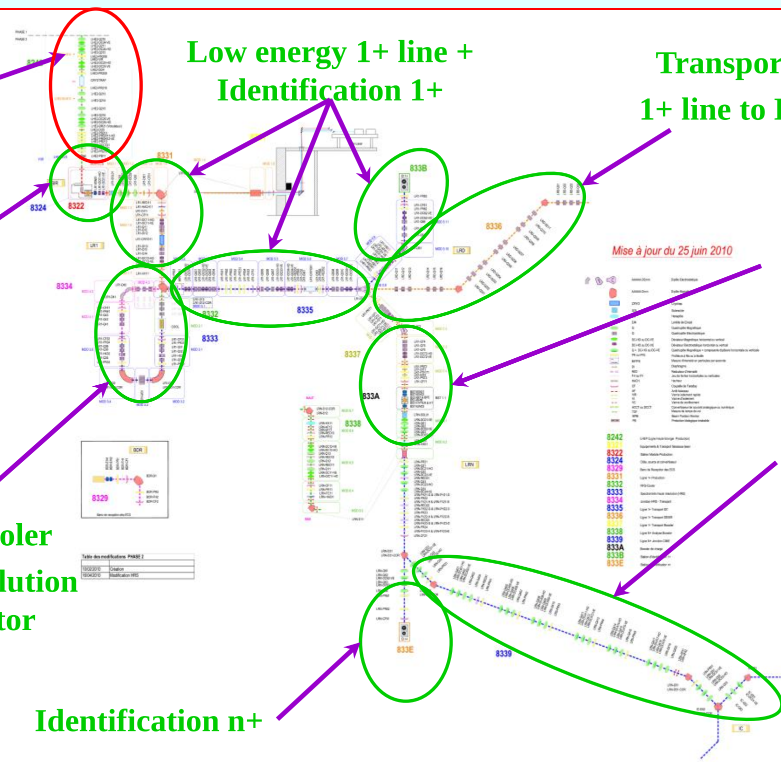
Imax=5mA

Energy : 40MeV, 14.5MeV/u

Line Length from LINAC=45m

Production module





Low energy 1+ line + Identification 1+

Transport Connection 1+ line to DESIR (100m)

Charge Booster + Analyses

RFQ-Cooler High Resolution Separator

N+ line up to CIME cyclotron and existing GANIL lines

Identification n+

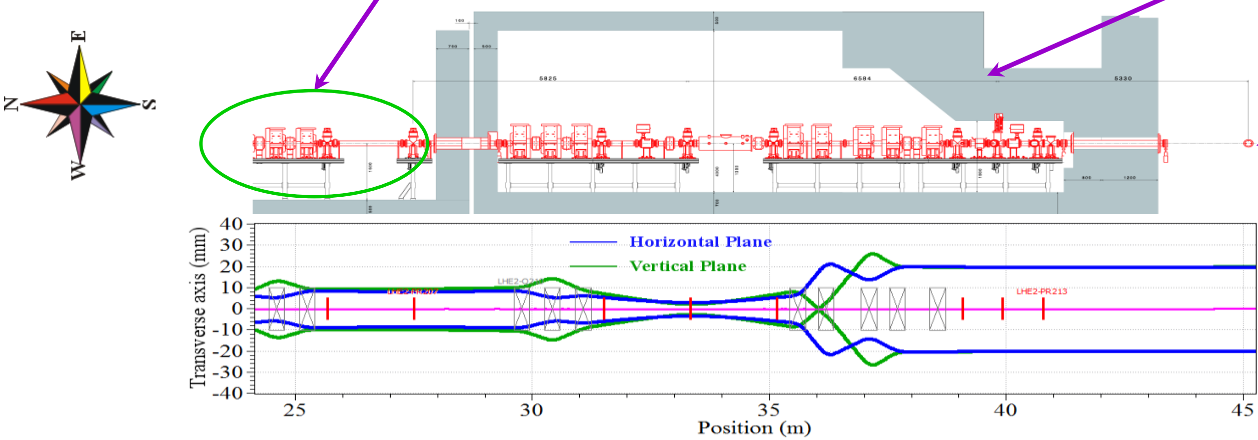
RIB PRODUCTION

HEBT to Production module can be divided in 2 parts

It must be seen at least in the point of view to safety aspects and 2 separated buildings.

Inside the accelerator building — Inside the production building

Production module focal point

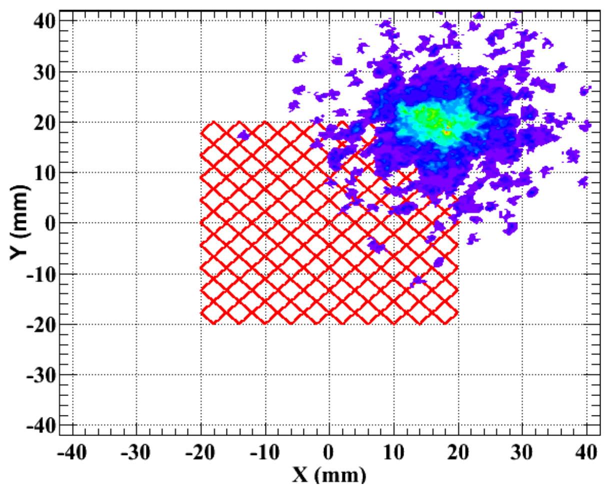


Requirement :
Beam Size on UCx
40mm at ±3RMS

Size & position on focal point stabilities/reproducibility will be difficult :

Residual Gas monitor + Segmented collimator

Under studies



Using UCx with 200kW D-beam impose to have beam raster magnet

B=120 G, f=20Hz

RIB PRODUCTION

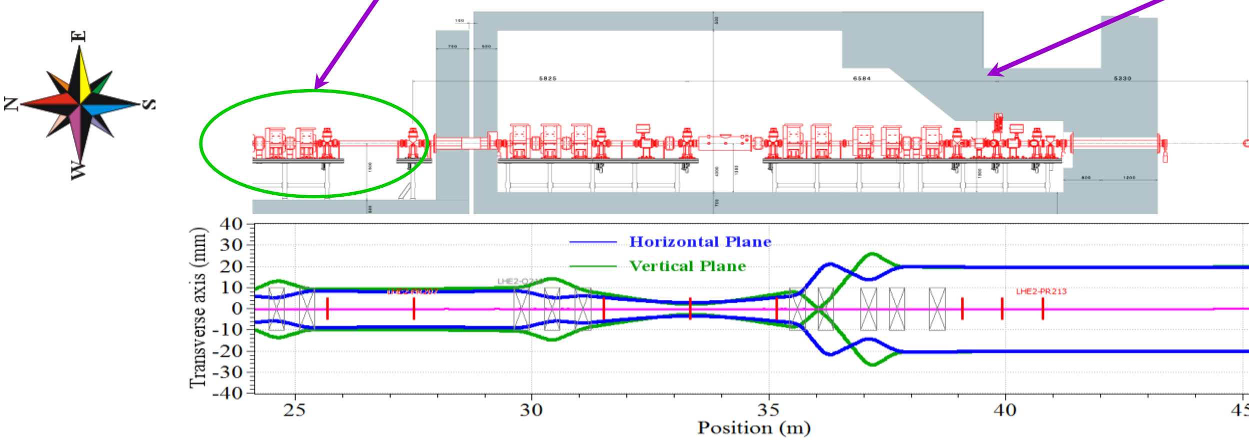
HEBT to Production module can be divided in 2 parts

It must be seen at least in the point of view to safety aspects and 2 separated buildings.

Inside the accelerator building

Inside the production building

Production module focal point

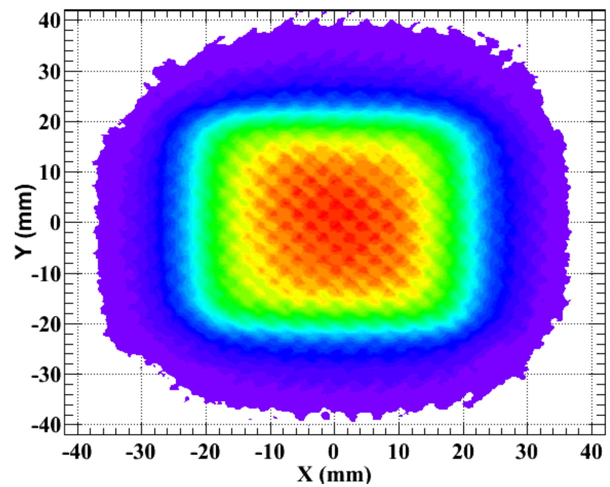


Requirement :
Beam Size on UCx
40mm at ±3RMS

Size & position on focal point stabilities/reproducibility will be difficult :

Residual Gas monitor + Segmented collimator

Under studies

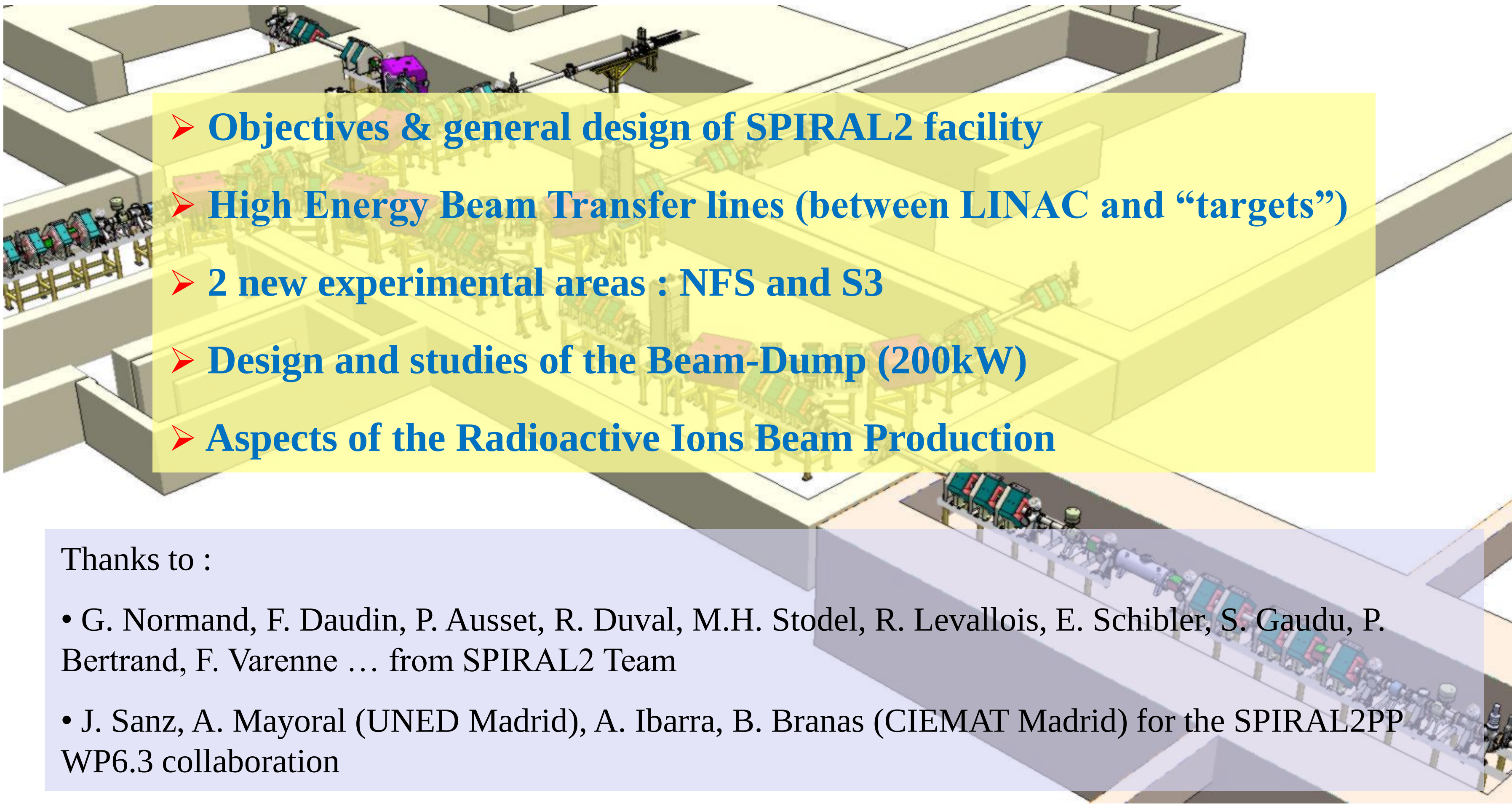


Using UCx with 200kW D-beam impose to have beam raster magnet

B=120 G, f=20Hz

Summary

HEBT lines for the SPIRAL2 facility.
What to do with accelerated beams ?



- **Objectives & general design of SPIRAL2 facility**
- **High Energy Beam Transfer lines (between LINAC and "targets")**
- **2 new experimental areas : NFS and S3**
- **Design and studies of the Beam-Dump (200kW)**
- **Aspects of the Radioactive Ions Beam Production**

Thanks to :

• G. Normand, F. Daudin, P. Ausset, R. Duval, M.H. Stodel, R. Levallois, E. Schibler, S. Gaudu, P. Bertrand, F. Varenne … from SPIRAL2 Team

• J. Sanz, A. Mayoral (UNED Madrid), A. Ibarra, B. Branas (CIEMAT Madrid) for the SPIRAL2PP WP6.3 collaboration