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

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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: $\beta=0.07$ and 0.12)
- HEBT: 90m
- -9.5m underground
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 $A/Q=3: 2-14.5\text{MeV/u}, 1\text{mA}^{18}\text{O}^{6+}, ^{48}\text{Ca}^{16+}$
- Upgrade: $A/Q=6: \text{up to } 8.5\text{MeV/u}$

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

$0.2\text{Tm}<B\rho<2.52\text{Tm}$
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

- 49 Quad: \( f = 128\text{mm}, L_m = 300\text{mm} \) (\( G_{\text{max}} = 10T/m \) & 13T/m)
- 8 dipoles: \( 45°, \rho = 1.5\text{m}, \text{gap} = 80\text{mm}, B_{\text{max}} = 1.68\text{T}, P = 56\text{kW} \)
- 3 buncher cavities \( \beta = 0.07 \)
- 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

Converter room: 6m long
Need to a versatile targets chamber
Targets: Be, C, Li, Al, Fe, Cu, SiC, ZrO₂
+ Dipole for Proton beam rejection
+ Beam stop

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

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

Neutrons Collimator
φ=20mm

Neutrons beam-dump

Collimator
f = 20 mm

D = 30 m
I = 8 µA

40 MeV d + Be
33 MeV d + Be
33 MeV d + C
36 MeV p + Li

Energy (MeV)
Neutrons For Science

Beam Dynamics for NFS: the case of 33MeV Protons

From LINAC to NFS converter

\[
\text{P: } 33\text{MeV, } \sigma_{x,y} \sim 4\text{mm, } \sigma_{x',y'} \sim 0.25\text{mrad, } \varepsilon \sim 1\pi\text{mm.mrad}
\]

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

From NFS converter to dump

\[
\text{P: } 30.8\text{MeV, } \sigma_{x,y} \sim 4\text{mm, } \sigma_{x',y'} \sim 5.8\text{mrad, } \varepsilon \sim 23.2\pi\text{mm.mrad}
\]

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

Dipole: \(\theta = 17^\circ\), \(\rho = 1\text{m}\), gap=80mm, \(B_{\text{r max}} = 1.3\text{T}\)

NFS Beam-dump: use the already designed BD of SP2 LME
\(\Phi = 100\text{mm, open angle=12}^\circ\)
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
I_{max}=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: $10^{13}$
- $B_{\rho_{max}} = 2$Tm
- $E_{\rho_{max}} = 10$ MV
- Mass resolution = 1/350

Momentum Achromat
Super Separator Spectrometer
Low Energy branch
Mass Separator: Elec+Mgn dipole
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, $^{239-242}$Pu, $^{248}$Cm
  - with Radius=6-15cm

The beam power density deposited 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:

Beam size on target:
RMS X=0.5mm, RMS Y: from 0.5 up to 2.5mm

Need to have $B_{max} < 1kG$, f~kHz with DDH
Need to have $B_{\text{max}} < 1\text{kG, f-kHz with DDH}$

**Super Separator Spectrometer**

**From LINAC to S3 target**

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The system can be based on the system designed by **Advanced Magnet Lab**:

“**Direct Double Helix™**”, http://www.magnetlab.com/technology/direct-double-helix/
Optimized Beam Stop Device for High Intensity Beams

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

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-mechanics, 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
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
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**HEBT-Prod RIB**
Beams: D, light ions $^{3,4}$He
Imax=5mA
Energy: 40MeV, 14.5MeV/u
Line Length from LINAC=45m

**Production module**

**RFQ-Cooler**
High Resolution Separator

**Identification n+**

**Low energy 1+ line + Identification 1+**

**Transport Connection**
1+ line to DESIR (100m)

**Charge Booster + Analyses**

**N+ line up to CIME cyclotron and existing GANIL lines**
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

**Using UCx with 200kW**
D-beam impose to have beam raster magnet
B=120 G, f=20Hz

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

Residual Gas monitor +
Segmented collimator
Under studies
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Production module focal point
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

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