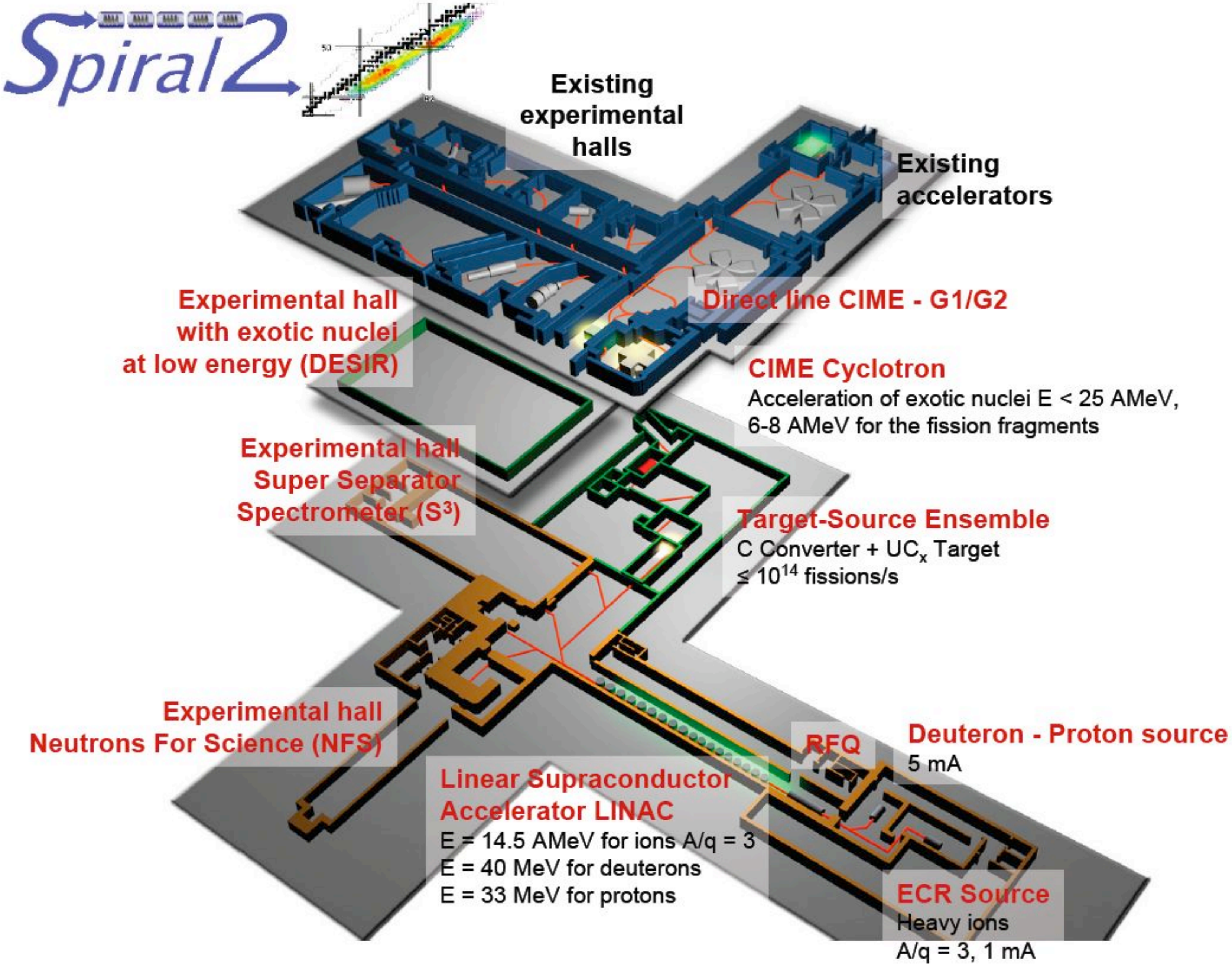
# Super Separator Spectrometer


Spiral2
Existing experimental halls
Existing accelerators
Experimental hall with exotic nuclei at low energy (DESIR)
Direct line CIME - G1/G2
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
≤ 10¹⁴ 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



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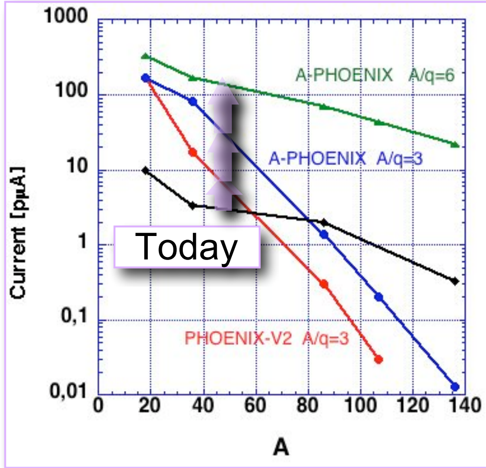
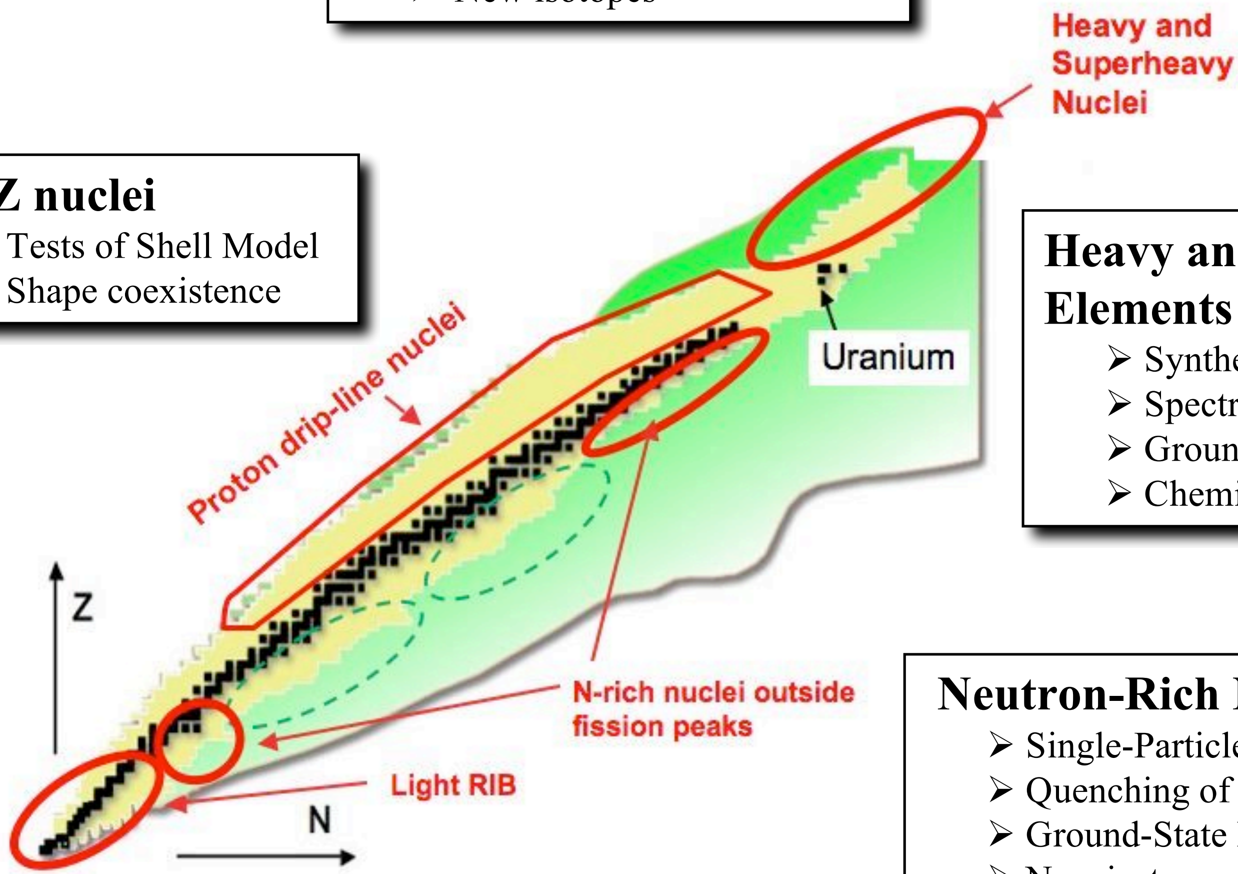
# Physics objectives

## Proton Dripline
- Single-Particle structure
- Development of Collectivity
- Ground-State Properties
- New isotopes




## N=Z nuclei
- Tests of Shell Model
- Shape coexistence



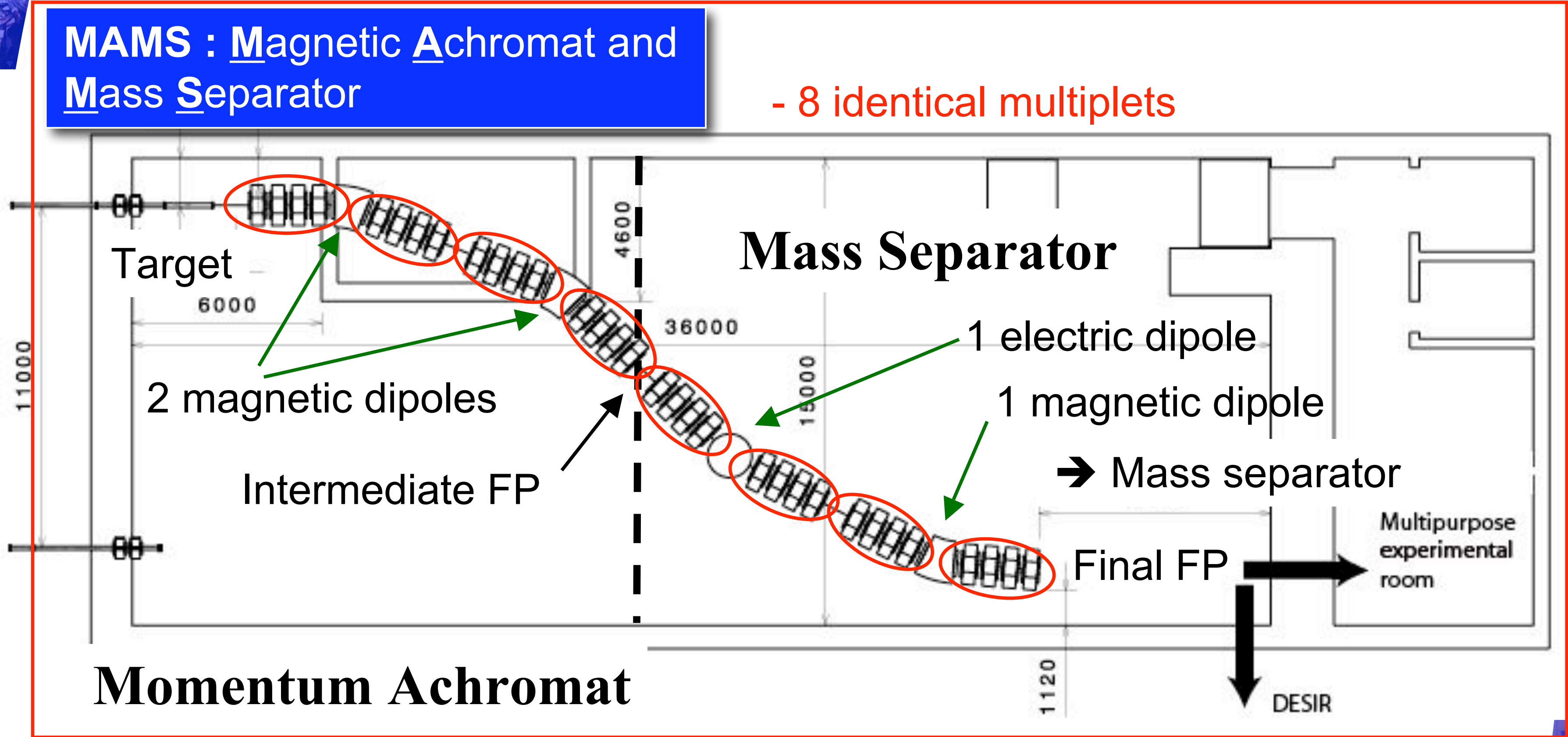

## Heavy and Superheavy Elements
- Synthesis
- Spectroscopy and Structure
- Ground-State Properties
- Chemistry

## Neutron-Rich Nuclei
- Single-Particle structure
- Quenching of Shell Gaps
- Ground-State Properties
- New isotopes

➲ **S3 physics white book, June 2008**

# Optics : Basic design (Argonne NL)

Principle : fulfil most of the requirements with one device




- ➔ Large angular acceptance : +/- 50 mrad X and Y
- ➔ Large Charge state acceptance : Bρ acceptance: +/- 10%
- ➔ Rejection of the beam : >$10^{13}$
- ➔ M/q selection : 1/350 resolution



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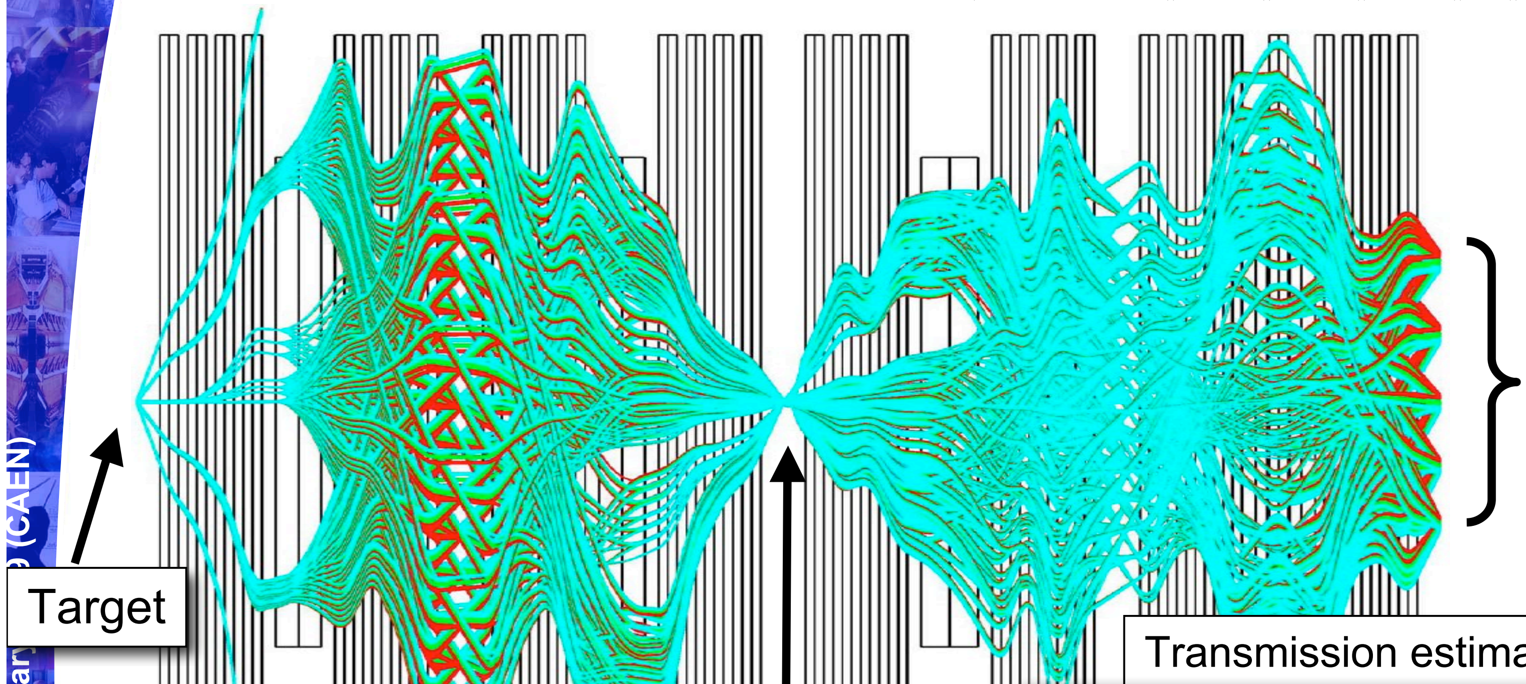
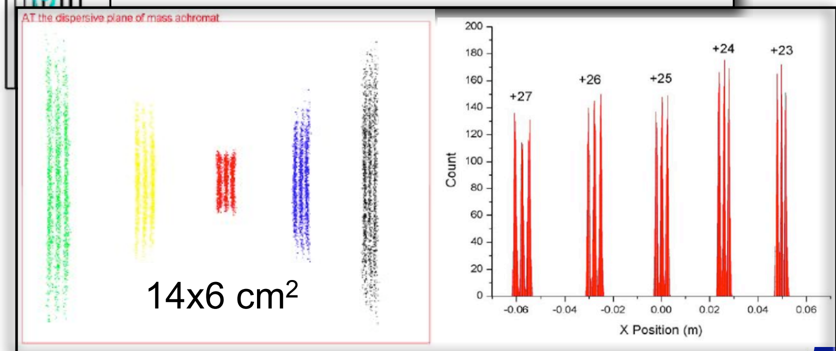
# Transmission of the full system

$^{48}Ca + ^{248}Cm \rightarrow ^{292}116 + 4n$

| | E [MeV/n] | <Br> [Tm] | <Er> [MV] | <Q> | <V> [cm/ns] | Δq (±2σ) [mrad] | dQ | dp/p[%] (±2σ) |
|---|---|---|---|---|---|---|---|---|
| Beam parameters $^{48}Ca$ | 4.92 | 0.88 | 27 | +17 | 3.0 | ± 8 | | ±0.2 |
| Recoil parameters $^{292}116$ | 0.131 | 0.58 | 3 | +25 | 0.5 | ± 50 (Y)<br>± 50 (X) | ± 2 | ±2.3 |




Transmission estimation ~50%



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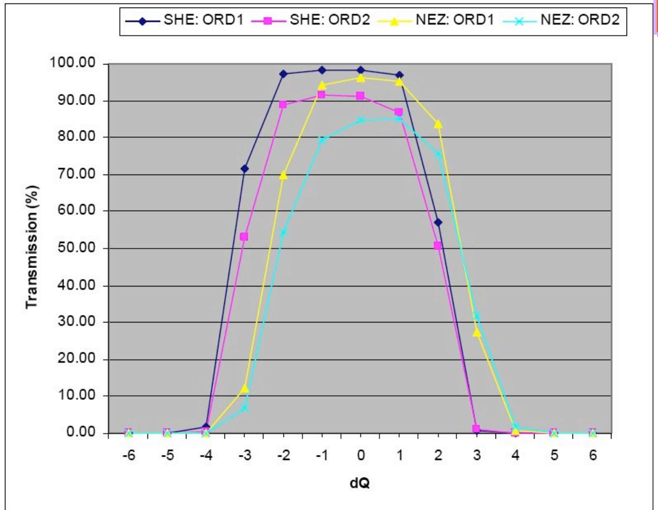
# Transmission of the full system

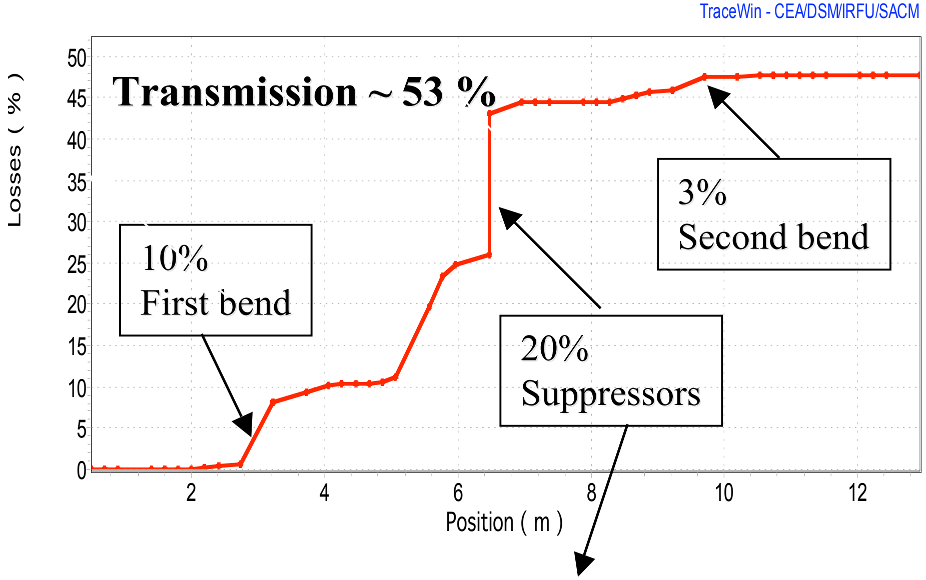
$^{48}Ca + ^{248}Cm \rightarrow ^{292}116 + 4n$

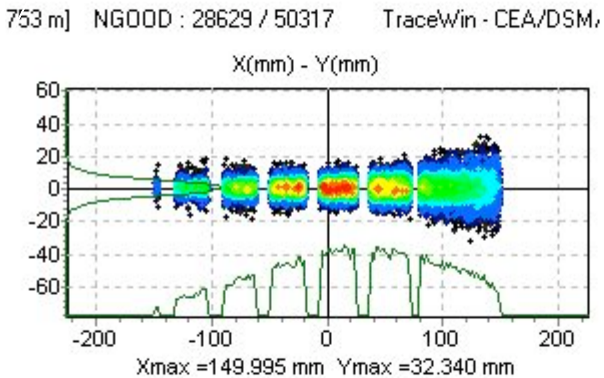
| Δq | | Transmission for SHE (%) 48Ca+248Cm | | | | % |
|---|---|---|---|---|---|---|
| | % | Order 1 | Order 2 | Order 3 | Order 5 | |
| -6 | 0 | 0.00 | 0.00 | 0 | | 0.00 |
| -5 | 0 | 0.00 | 0.00 | 0 | | 0.00 |
| -4 | 0 | 1.60 | 0.31 | 0.545 | | 0.00 |
| -3 | 3.5 | 71.67 | 53.20 | 57.71 | | 2.51 |
| -2 | 6.6 | 97.44 | 88.74 | 85.58 | | 6.43 |
| -1 | 10.5 | 98.39 | 91.57 | 85.6 | | 10.33 |
| 0 | 14.1 | 98.31 | 91.26 | 85.19 | 80.91 | 13.86 |
| 1 | 16.1 | 96.99 | 86.84 | 77.01 | | 15.62 |
| 2 | 15.6 | 57.00 | 50.66 | 38.57 | | 8.89 |
| 3 | 12.8 | 0.51 | 1.14 | 1.35 | | 0.07 |
| 4 | 8.9 | 0.00 | 0.00 | 0 | | 0.00 |
| 5 | 5.2 | 0.00 | 0.00 | 0 | | 0.00 |
| 6 | 2.6 | 0.00 | 0.00 | 0 | | 0.00 |
| | | | | | | 57.70 |




*ANL Monte Carlo simulations*

$^{58}Ni + ^{46}Ti \rightarrow ^{100}Sn + 4n$




*CEA/DSM/IRFU/DPhN Monte Carlo simulations*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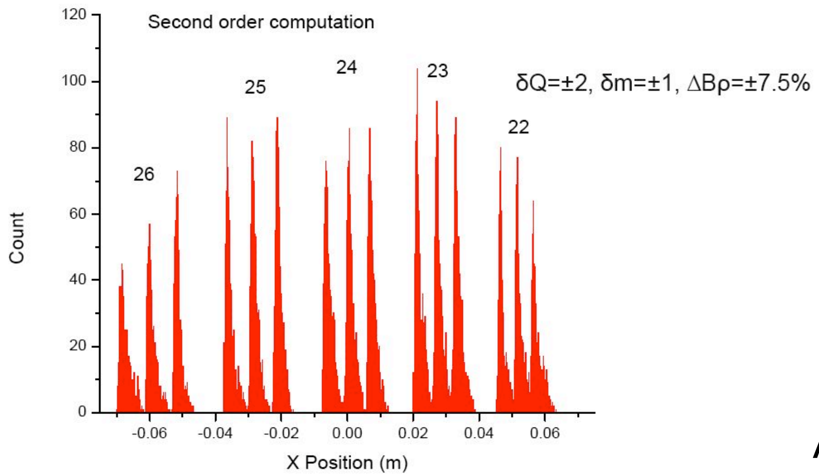
# Transmission of the full system

⇨ 5 charge states will be transmitted to the focal plane covering a 14Lx6H cm2 area.
⇨ The expected transmission efficiency is of the order of 50%.

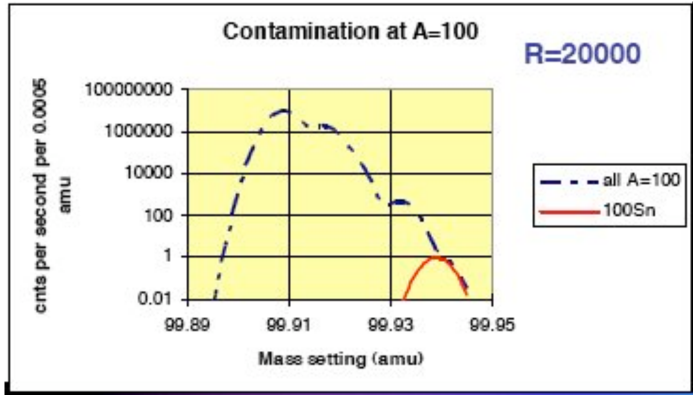
$^{58}Ni$ + Ti ⇨ $^{100}Sn$ (1 Mev/A, 20 pps + $10^8$ isobars/s)

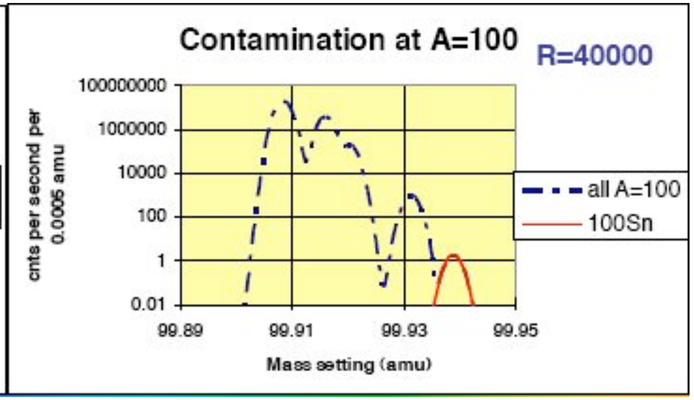



Plot showing position of mass line

| Isotope | Mass (amu) | Separation (M/ΔM) |
|---|---|---|
| Sn100 | 99.938954 | ----- |
| In100 | 99.931149 | 12800 |
| Cd100 | 99.920230 | 5330 |
| Ag100 | 99.916069 | 4370 |
| Pd100 | 99.908505 | 3280 |

A=100 Isobar mass contamination @ FP



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# Infrastructure

September 08 : Choise of the Project Management Team (“MOE”)
May 08 : request for the building permit



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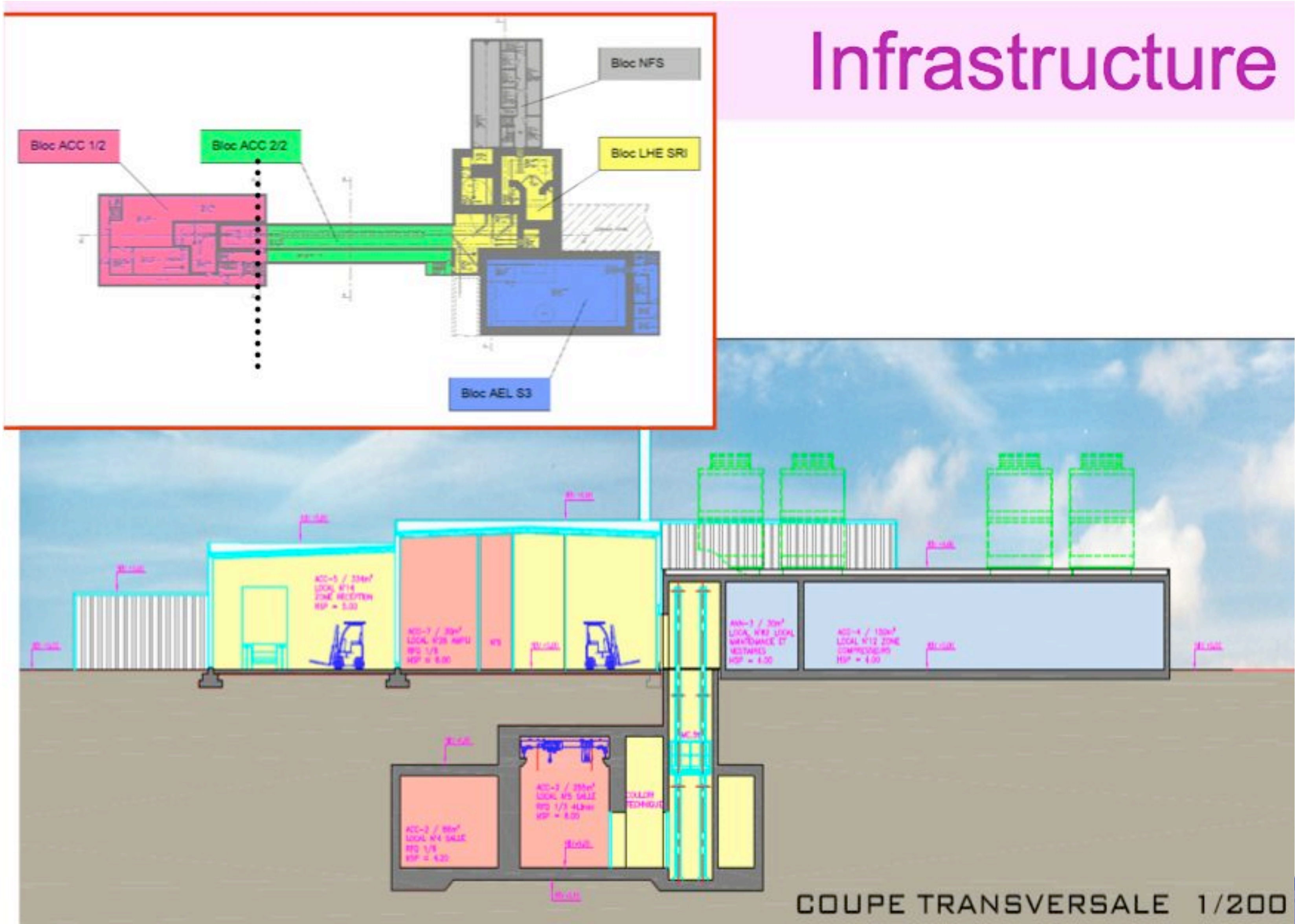
# Infrastructure



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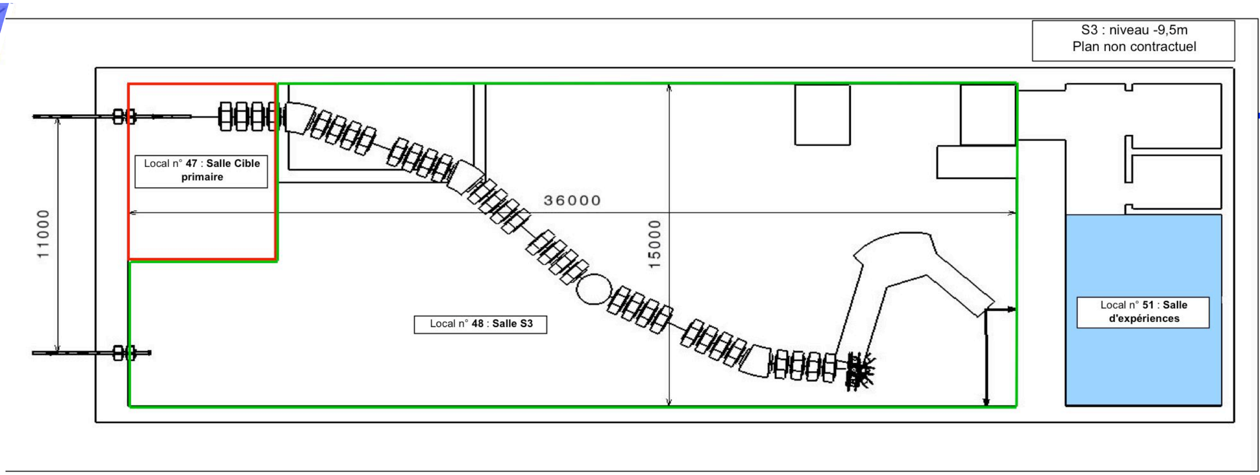
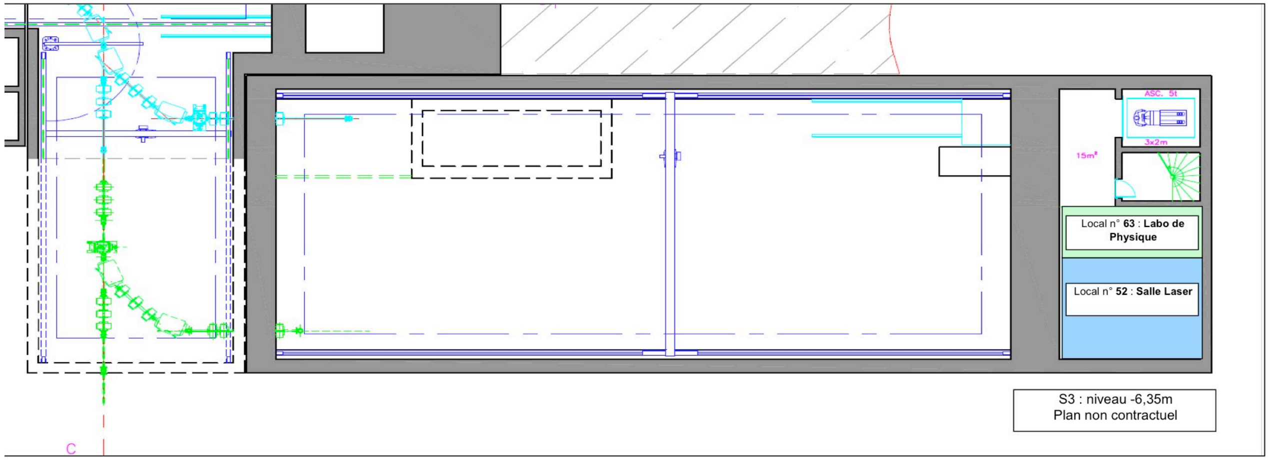
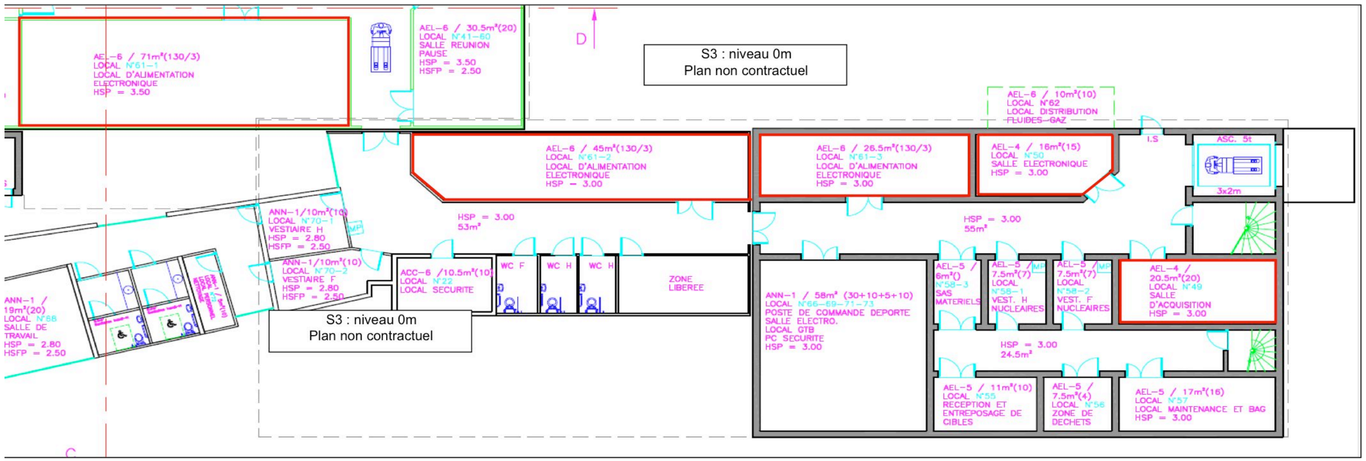
# phase 1




**-9m**




**-6m**




**Ground level**



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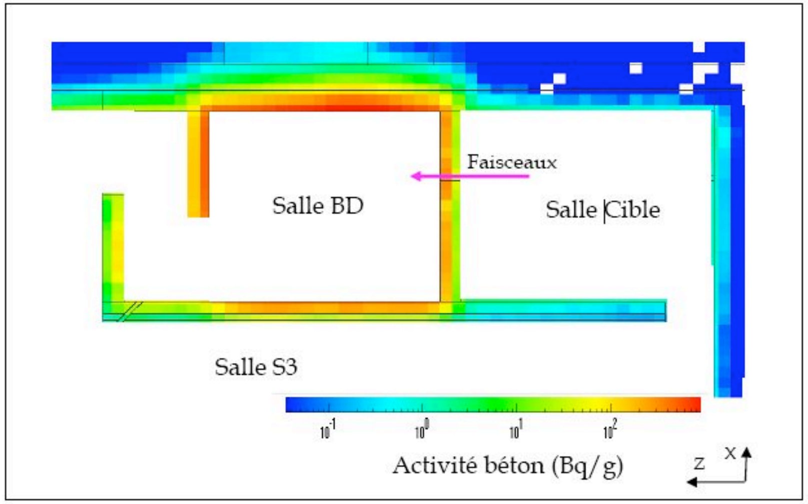
# Nuclear Design

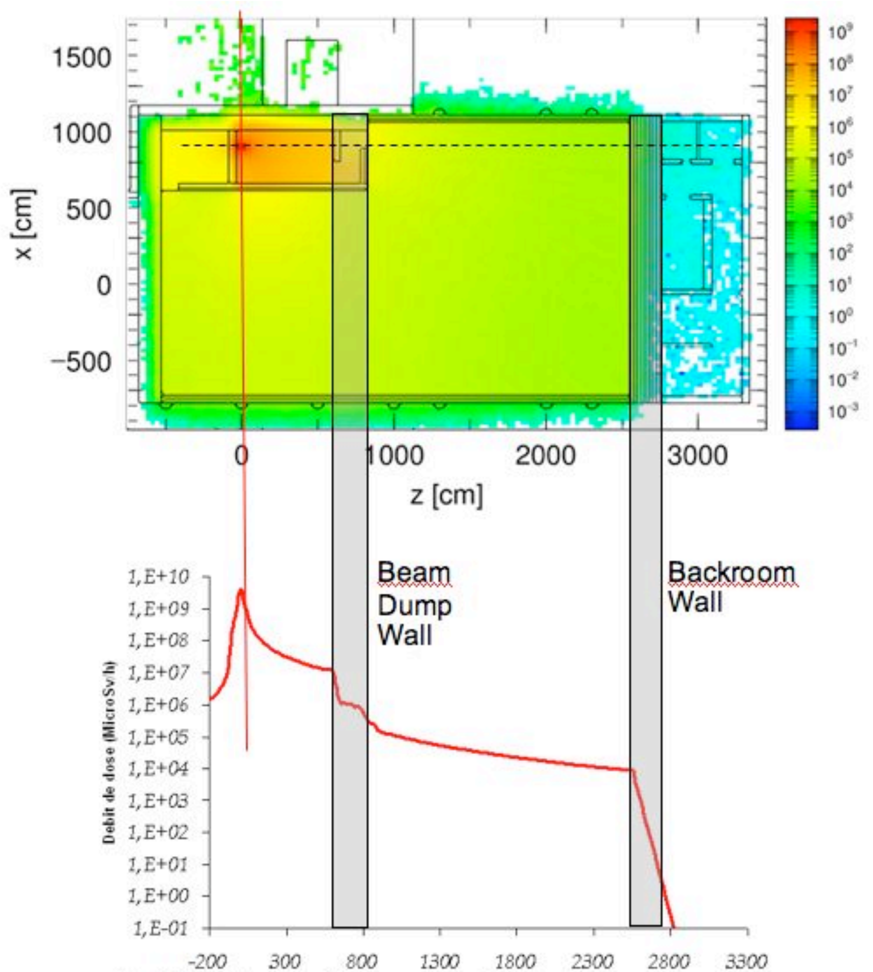
Heavy ion beams from LINAG
- ⇨ from C to U
- ⇨ 2 to 15 A.MeV
- ⇨ up to $10^{15}$ions/sec
- ⇨ up to 50kW
- ⇨ during 6 months/year (for 20 years!)

Reference beam ⇨ $^{12}C$ @ 14.5 MeV/u
Intensity = 1mA ($1.6\times10^{15}$ pps)




Concrete activation

Neutrons fluxes in the $S^3$ cave vicinity




Up: 2D distribution of the number of neutrons
Down: Dose (µSv/h) due to the neutrons on the 0° (beam) direction (corresponding of the dashed line)

SENAC (Irfu)

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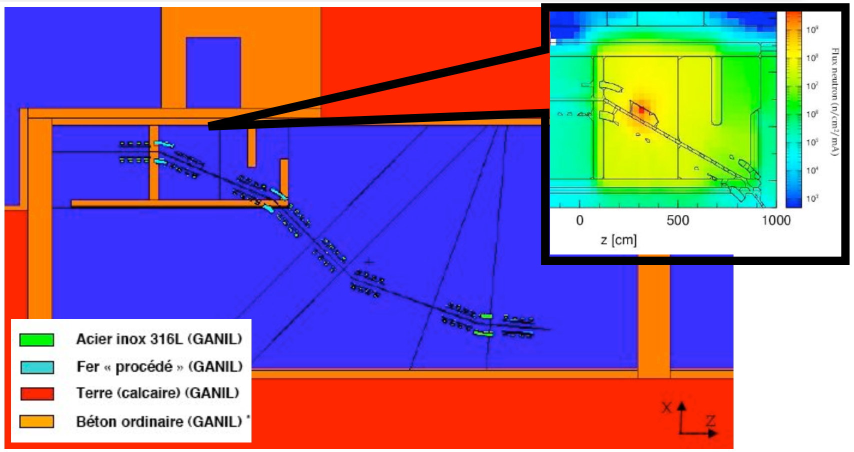
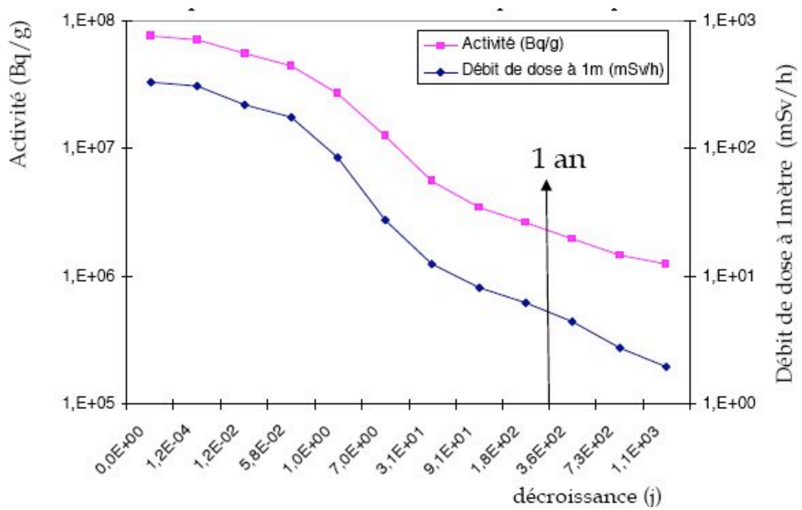
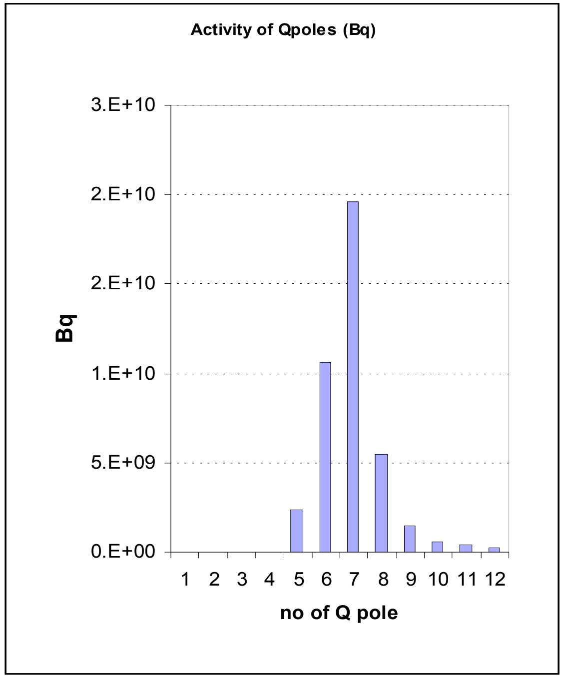
# Nuclear Design

⇨ activation & radiation damage

Calculations A. van Lauwe (SENAC)




The 5th to 8th Qpoles
are strongly activated
(Warm Qpoles, iron+copper)

Dose rate from the beam dump is not negligible !
➔ Limit any human intervention in the zone
➔ Shielding is required

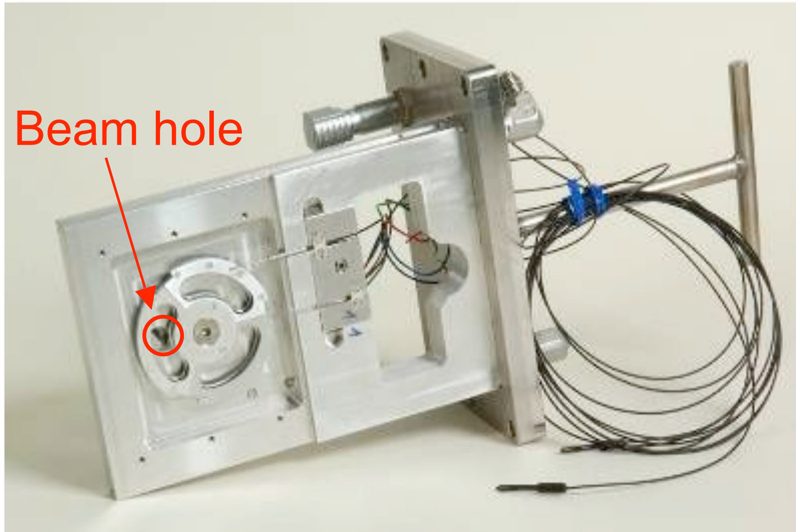
# High power target stations

## Stable

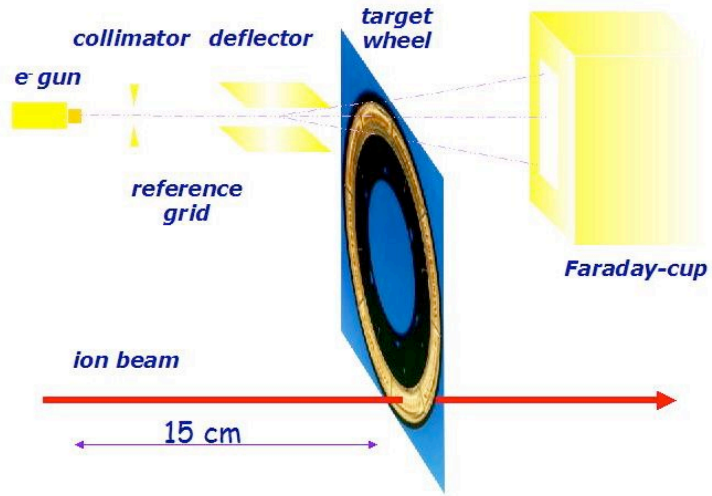
$^{208}Pb$, $^{209}Bi$, Ni, Ca, C
( R ≈ 25 cm)


## Actinides

$^{232}Th$, $^{238}U$, $^{239}Pu$, $^{242}Pu$, $^{244}Pu$, $^{248}Cm$, $^{249}Cf$ (?)
≈ 45 mg ≈ $10^2$ – $7*10^9$ Bq
( R=6-15 cm)




Target thickness and homogeneity
- RBS method
- Electron gun
- Pyrometer
- Infrared cameras
- Scintillators …




*e- Beam Diagnosis*
*R. Mann (patent # DE 102 42 962 A1)*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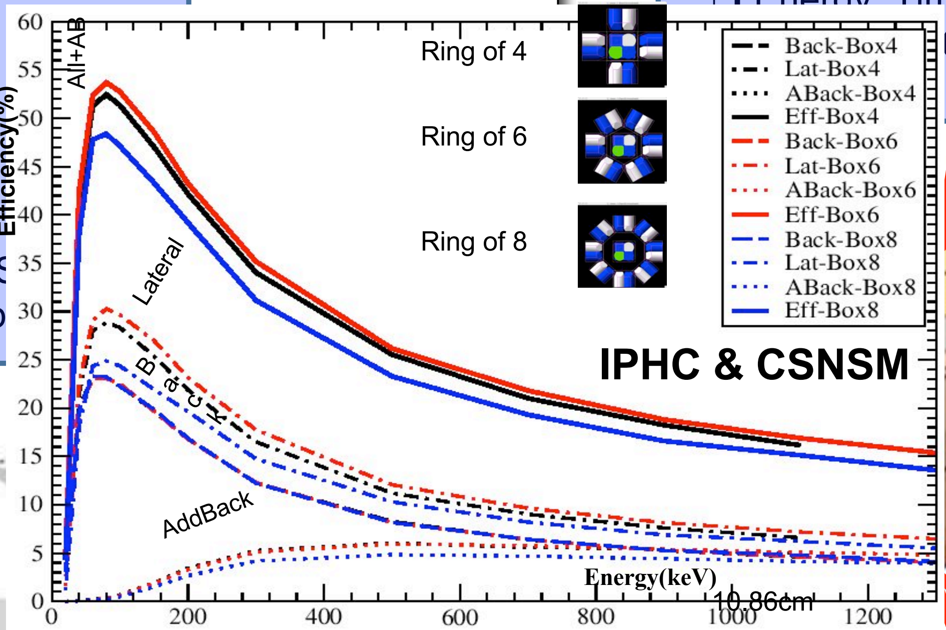
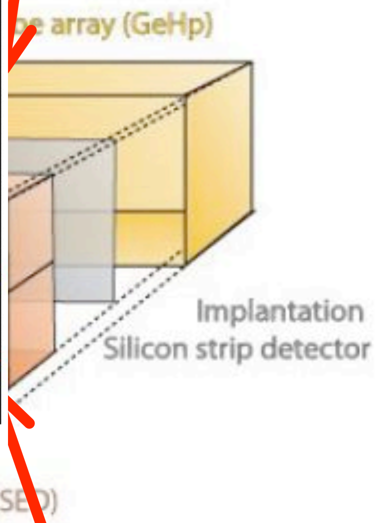
# Base detection system

- Number of channels ~ 650
- Counting rate = 1kHz/channel
- Charge pre-amps
- 20 keV@ 5 MeV α
- 5-10 MeV Heavy ions
- 2 gains
  - ✓ High gain for α
  - ✓ low gain for HI
- 16384 channels ADC
- Energy, Time Stamp, PS
- Sampling 100 MHz 14 b

…scopy setup :
…tection

- Number of channels = 32
- Counting rate = 1kHz/core
- 2.3 keV @ 1.3 MeV
- Energy, Time Stamp, PSA
- …00 MHz, 14 bits




**Planning:**
2009-2010 : Detail design study
2011: Fabrication

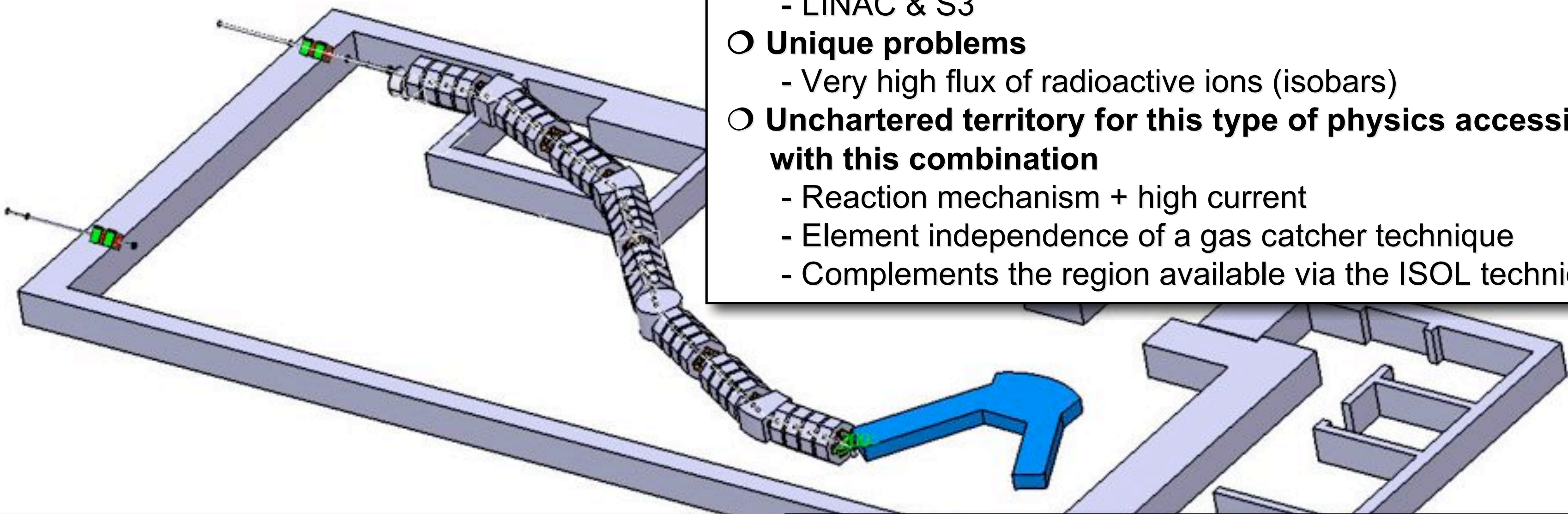
Number of channels = 200
Counting rate = 1kHz/channel
Resolution : 10%

⇨ 5 charge states are expected in 14×6 cm²

Number of channels = 40
•High gain pour α
•Low gain pour HI

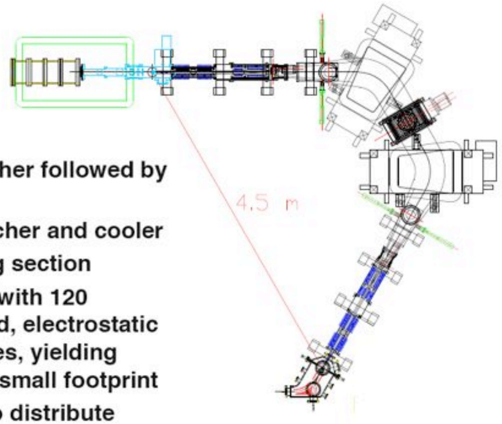
# $S^3$ Low energy branch

- ❍ **Unique combination**
  - LINAC & S3
- ❍ **Unique problems**
  - Very high flux of radioactive ions (isobars)
- ❍ **Unchartered territory for this type of physics accessible with this combination**
  - Reaction mechanism + high current
  - Element independence of a gas catcher technique
  - Complements the region available via the ISOL technique



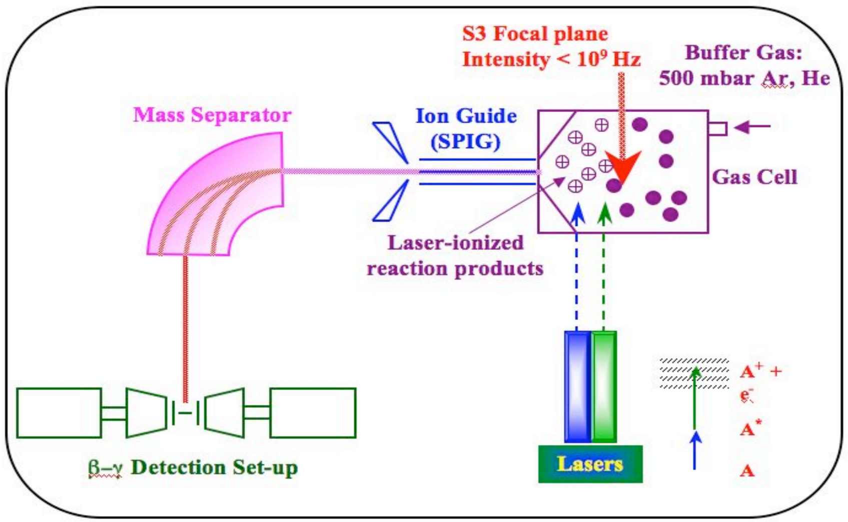
## Gas Catcher + high-resolution mass separation

*Possible gas catcher and mass separator layout for $S^3$*




- High intensity RF gas catcher followed by gas cooler
- 50 kV platform for gas catcher and cooler
- Acceleration and matching section
- High resolution separator with 120 degree total magnetic bend, electrostatic quadrupoles and multipoles, yielding 20000 mass resolution on small footprint
- Electrostatic switchyard to distribute beam to experiments in S3 hall, or in DESIR hall, or to post-accelerator

## Laser ion source + mass separation




LISOL (Leuven)



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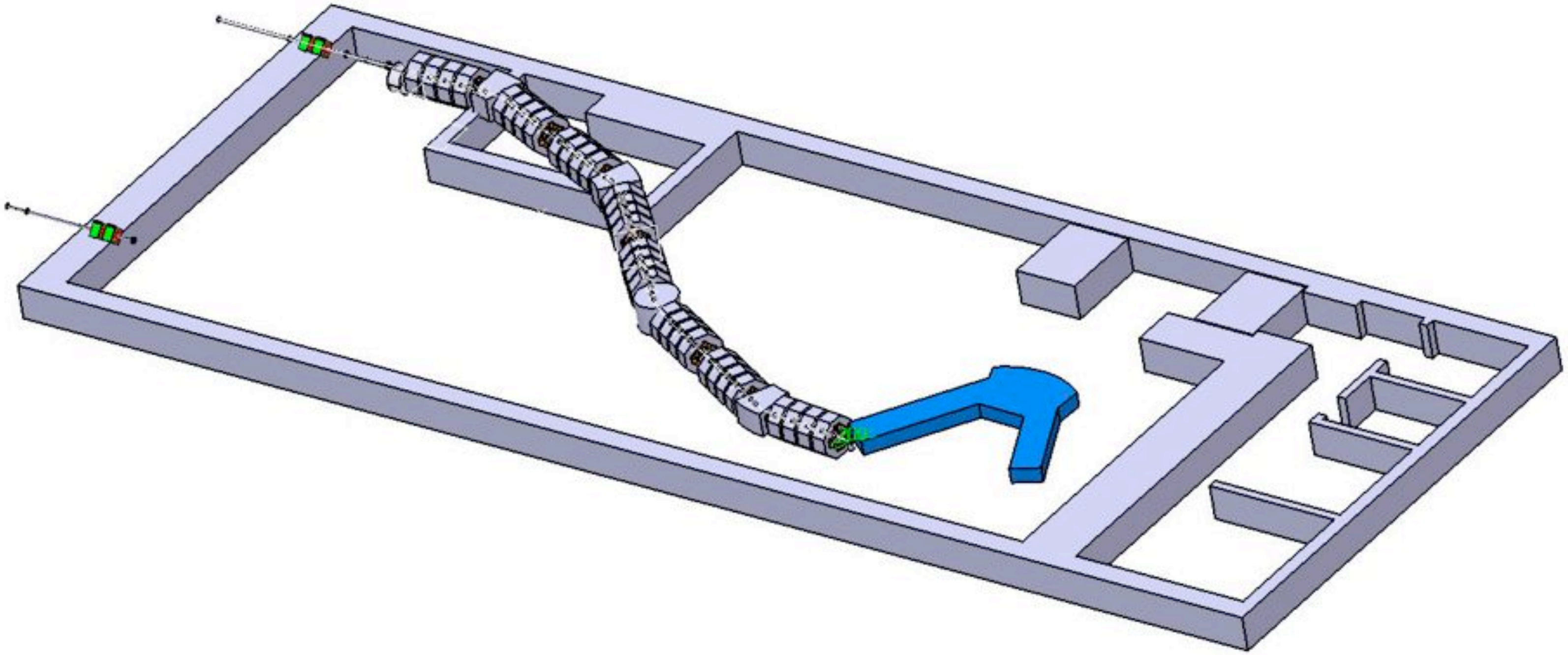
# $S^3$ Low energy branch



Construction and operation of a gas catcher optimized for a 100Sn research program.
Argonne group: G. Savard, J. Clark, A. Levand, plus a new post-doc and a student.
a. We propose to construct and install a high-rate helium gas catcher to deliver low energy beams of rare isotopes for precision lifetime and mass measurements in the 100Sn region following S3. This facility will remain available for delivery of low energy beams to the apparatus at DESIR following the commissioning of that facility. Budget ~$1.9M.



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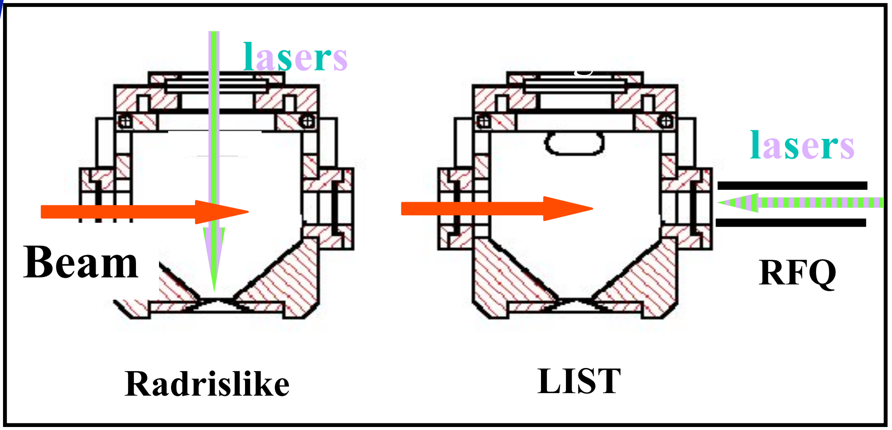
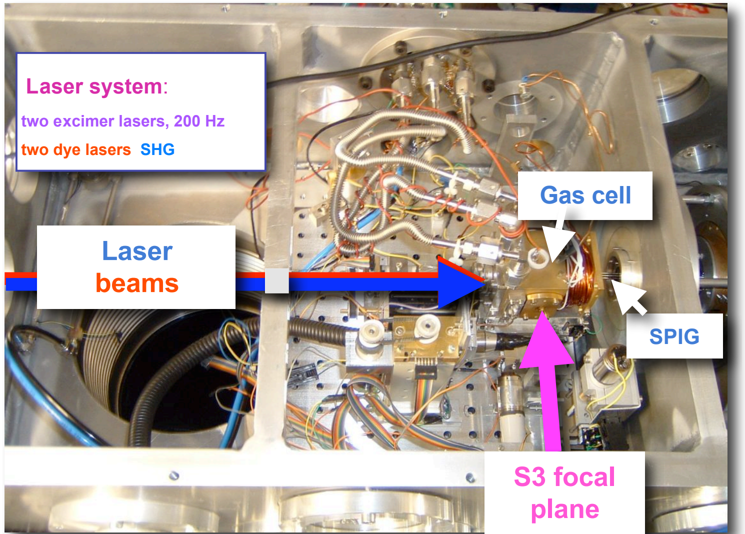
# $S^3$ Low energy branch

**K.U. Leuven** ⇨ design a gas catcher for $S^3$ and move its related laser equipment and mass separator to Ganil (MoU in preparation)




- ❍ Project description *(S. Franchoo IPNO)*
  - ⇨ first draft for Spiral2 week January 2009
  - ⇨ Integration with ANL proposed setup
- ❍ Design for an ion catcher *(K.U. Leuven)*
  - ⇨ concept & drawings
  - ⇨ ion flow simulations
  - ⇨ electrical extraction fields
  - ⇨ coupling to RFQ
- ❍ Integration study *(GANIL)*
  - ⇨ assessment of equipment at Leuven
  - ⇨ safety in particular gas exhaust
  - ⇨ coupling to mass separator & DESIR


**K.U. Leuven, IPNO & GANIL**

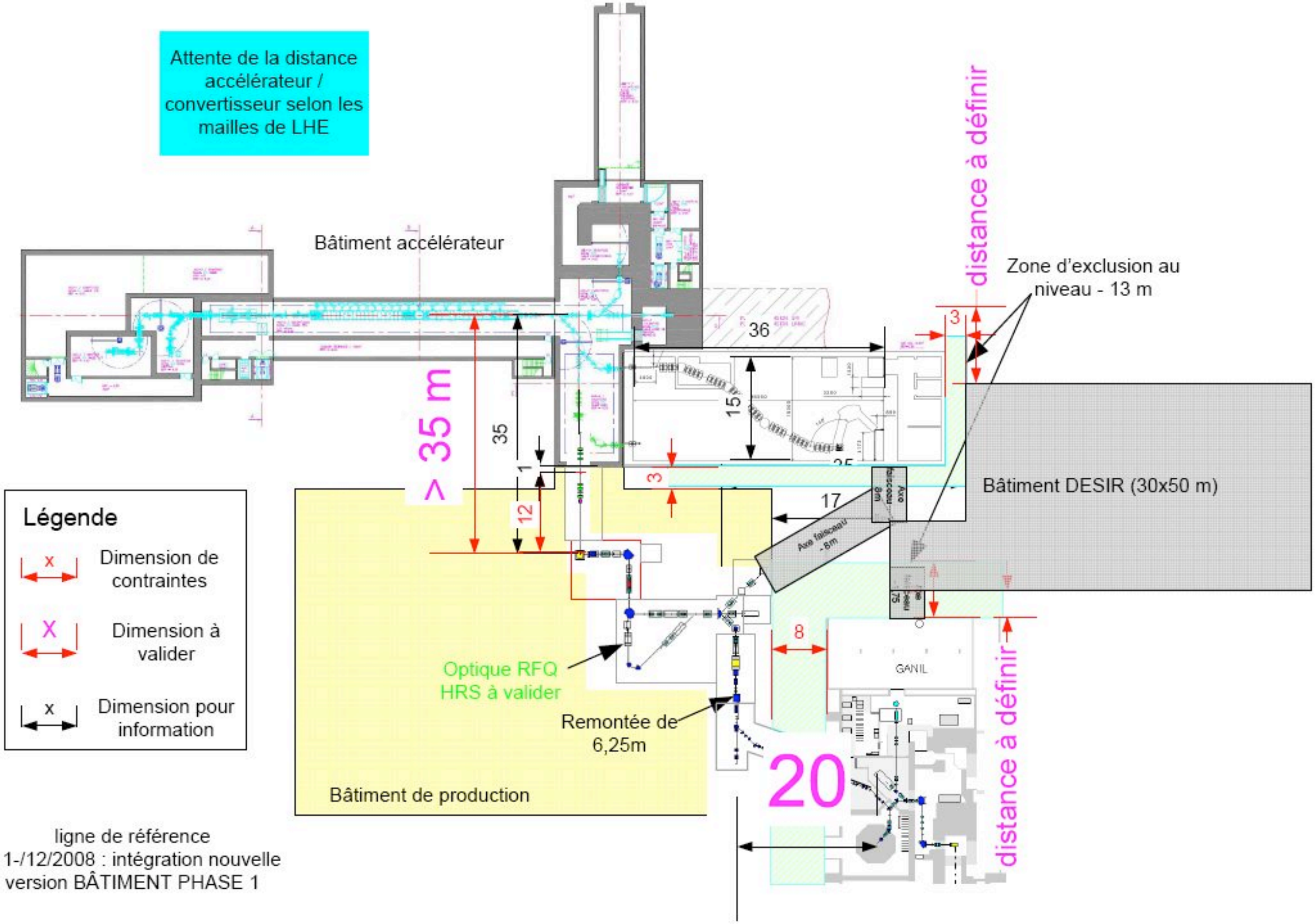
# $S^3$ Low energy branch

❍ **Implementation of low energy branch**

- Need layout and output beam properties of recoil spectrometer to make more realistic design
- Decide on key experiments
- Complete layout compatible with gas catcher and Leuven ion source
- Decide on first low-energy experimental experiment and location
- where else should be send those beams
- …

❍ **Desirable early implentation of low energy experimental equipment**

- Decay station …. Needed for both physics and diagnostics / tuning
- Penning trap system for mass measurements
- Laser spectrocopy system … either with beam or in source, or both
- Total absorption spectrometer
- …


Attente de la distance accélérateur / convertisseur selon les mailles de LHE
Bâtiment accélérateur
distance à définir
Zone d'exclusion au niveau - 13 m
36
3
15
35
> 35 m
1
12
3
17
Axe faisceau - 8m
Bâtiment DESIR (30x50 m)
8
GANIL
Optique RFQ HRS à valider
Remontée de 6,25m
20
distance à définir
Bâtiment de production
Légende
Dimension de contraintes
Dimension à valider
Dimension pour information
ligne de référence
V 1-/12/2008 : intégration nouvelle version BÂTIMENT PHASE 1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# Spiral 2 beam schedule scenari

## AEL priority

**SPIRAL 2**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | Nb. semaines |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Janvier | | | | Février | | | | Mars | | | | | Avril | | | | Mai | | | | | Juin | | | | Juillet | | | | | Août | | | | Sept. | | | | Oct. | | | | | Nov. | | | | Dec. | | | |
| Fonctionnement LINAG | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | 44 |
| Maintenance LINAG | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 | 1 | 1 | | | | | | | | | | | | | | | | 1 | 1 | 8 |
| AEL | X | X | 1 | 1 | 1 | 1 | 1 | | | | 1 | 1 | 1 | 1 | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | | | | 1 | 1 | 1 | 1 | 1 | | X | X | X | X | 1 | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | 1 | 1 | | | | X | X | 31 |
| CASEMATE JAUNE | X | X | | | | | | 1 | 1 | 1 | | | | | | 1 | | | | | | | | | | | | | | | 1 | X | X | X | X | | | | | | | | | | | | | | | | X | X | 5 |
| CASEMATE ROUGE | X | X | | | | | | | | | | | | | | | | | | | | | 1 | 1 | 1 | | | | | | | X | X | X | X | | | | | | 1 | 1 | | | | | | 1 | 1 | 1 | X | X | 8 |
| Aires GANIL | X | X | | | | | | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | X | X | X | X | | | | | | 1 | 1 | | | | | | | | | X | X | 4 |
| DESIR | X | X | | | | | | | | 1 | | | | | | 1 | | | | | | | 1 | 1 | 1 | | | | | | 1 | X | X | X | X | | | | | | | | | | | | | 1 | 1 | 1 | X | X | 9 |

## Standard

**SPIRAL 2**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | Nb. semaines |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Janvier | | | | Février | | | | Mars | | | | | Avril | | | | Mai | | | | | Juin | | | | Juillet | | | | | Août | | | | Sept. | | | | Oct. | | | | | Nov. | | | | Dec. | | | |
| Fonctionnement LINAG | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | 44 |
| Maintenance LINAG | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 | 1 | 1 | | | | | | | | | | | | | | | | 1 | 1 | 8 |
| AEL | X | X | 1 | 1 | 1 | | | | | 1 | | | | | 1 | 1 | 1 | | | | | 1 | 1 | | | 1 | 1 | | | | | X | X | X | X | 1 | | | | | | | 1 | | | 1 | 1 | 1 | | | X | X | 16 |
| AUTRES CIBLES | X | X | | | | | | | | | | | | | | | | 1 | 1 | 1 | 1 | | | 1 | 1 | | | | | | | X | X | X | X | | | | | | | | | | | | | | 1 | 1 | X | X | 8 |
| CIBLES Ucx | X | X | | | | 1 | 1 | 1 | 1 | | 1 | 1 | 1 | 1 | | | | | | | | | | | | | | 1 | 1 | 1 | 1 | X | X | X | X | | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | 1 | | | | | | X | X | 20 |
| Aires GANIL | X | X | | | | | | 1 | 1 | | | | 1 | 1 | | | | | 1 | 1 | 1 | | | | | | | | 1 | 1 | 1 | X | X | X | X | | | | 1 | 1 | 1 | 1 | | 1 | 1 | | | | 1 | 1 | X | X | 18 |
| DESIR | X | X | | | | 1 | 1 | | | | 1 | 1 | | | | | | 1 | | | | | 1 | 1 | 1 | | 1 | 1 | | | | X | X | X | X | | 1 | 1 | | | | | | | | | 1 | 1 | | | X | X | 14 |
| Changements ECS | X | X | | 1 | 1 | | | | | | | | | | 1 | 1 | 1 | | | | | 1 | 1 | | | 1 | 1 | | | | | X | X | X | 1 | 1 | | | | | | | | | | 1 | 1 | 1 | | | X | X | 14 |

- One production cave: 28-33
- $Uc_x$ target: 20-25
- AEL•s: 16-31
- DESIR (with SPIRAL1 et 2): 30-34
- CIME RIB (SPIRAL 1 et 2): 24-25

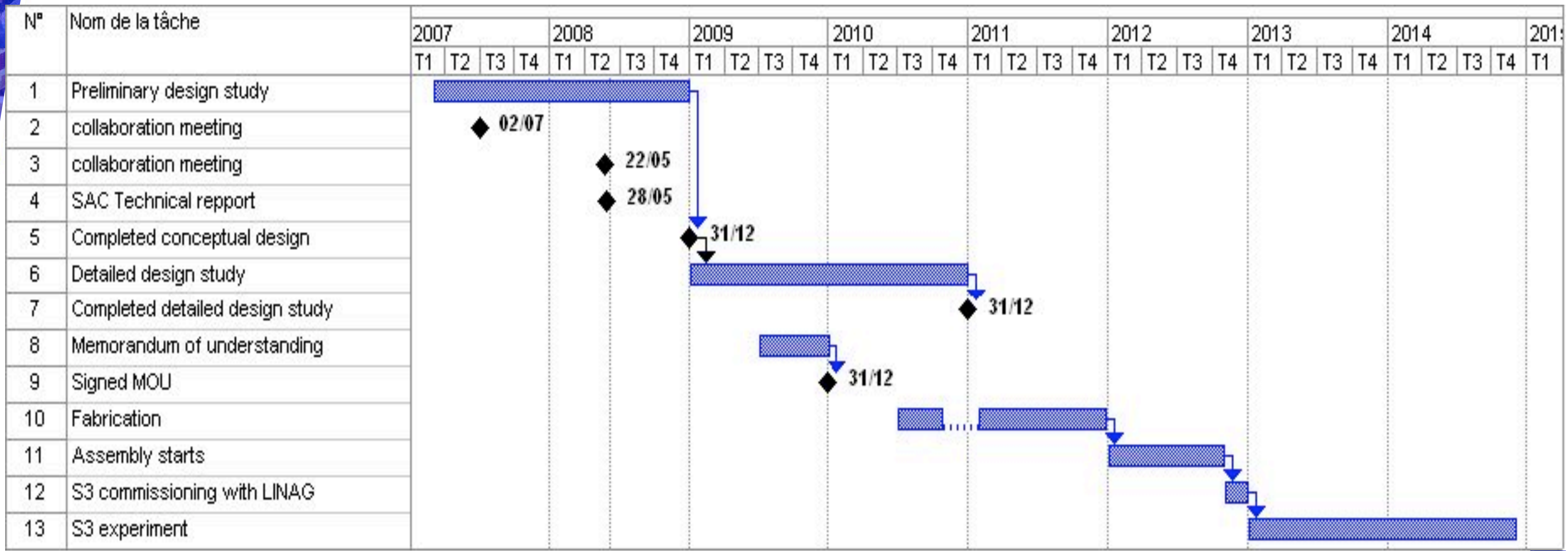




H. Savajols

# S3 schedule

- **Design & Construction of Superconducting multiplets could be done within 3 years**




- Evaluation by SPIRAL2 Scientific Advisory Committee (June 2008)

  **S3 recommended for construction with high priority**

- Signatures of the MoU expected 2009-2010
- **Cash flow will be an issue initially with lots of spending in 2010 already**



H. Savajols