

- ✓ **SPIRAL 2 Detailed Design Study 2002-2005**
- ✓ **FAIR & SPIRAL 2 recognised by NuPECC and ESFRI (List of Opportunities): February - March 2005**
- ✓ **Decision on the construction of SPIRAL 2 was taken by the French Ministry of Research on May 24th, 2005**
- ✓ **Project leader (M. Jacquemet) and scientific leader (M.L.) of SPIRAL 2 were appointed this week**

Existing GANIL Accelerators

CIME Cyclotron  
Acceleration of RI Beams  
 $E < 25$  A MeV

Existing GANIL  
Exp. Area

Direct beam line CIME-  
G1/G2 caves

Low energy RNB  
(LIRAT)

Production Cave  
C converter+ $UC_x$  target  
 $\leq 10^{14}$  fissions/s



Stable Heavy-Ion Exp. Hall

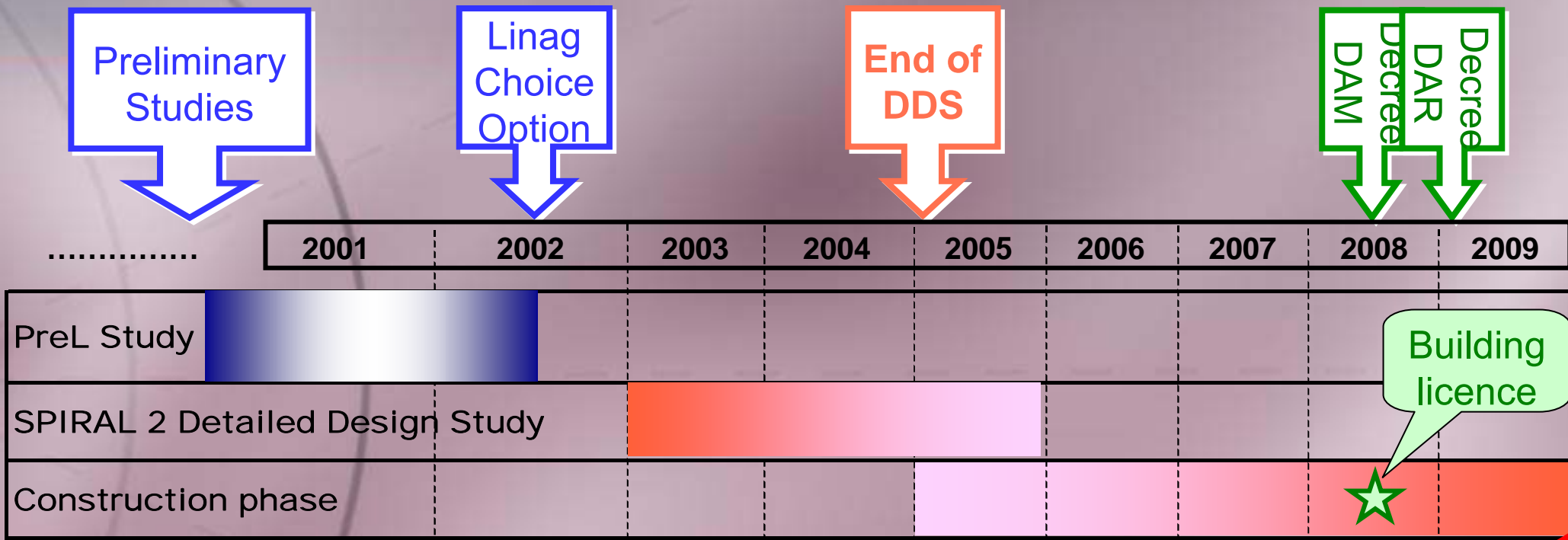
RFQ

Deuteron source  
5mA

Superconducting LINAC  
 $E = 14.5$  A MeV for heavy Ions  $A/q=3$   
 $E = 40$  MeV for deuterons

Heavy-Ion ECR source  
( $A/q=3$ ), 1mA

# Time Schedule & Budget

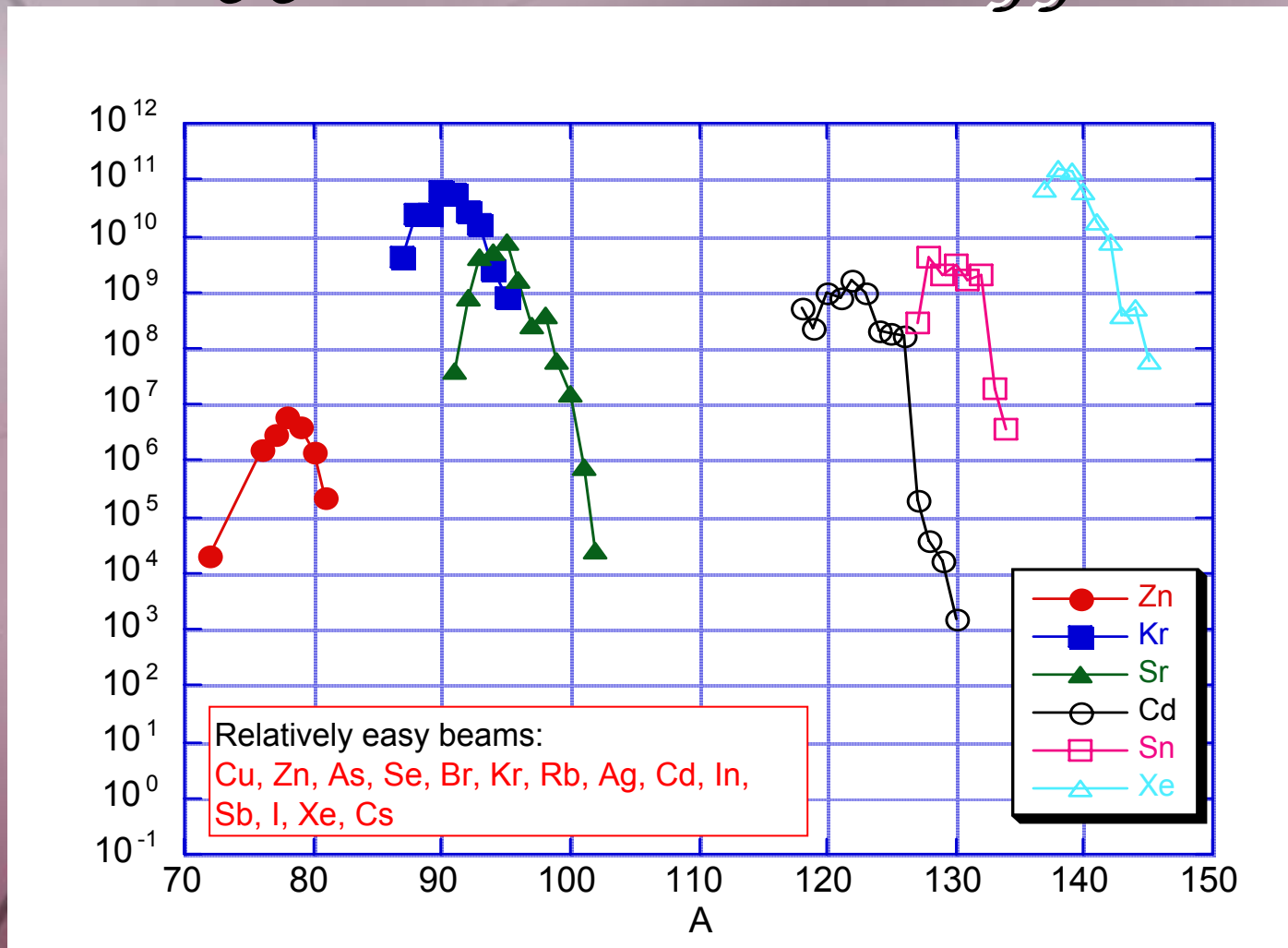


**Investment Budget 95,2 M€** (including contingency)  
**Total Budget 130,2 M€**  
 (20 MEuros from EU - 7<sup>th</sup> FP and international collaborations)

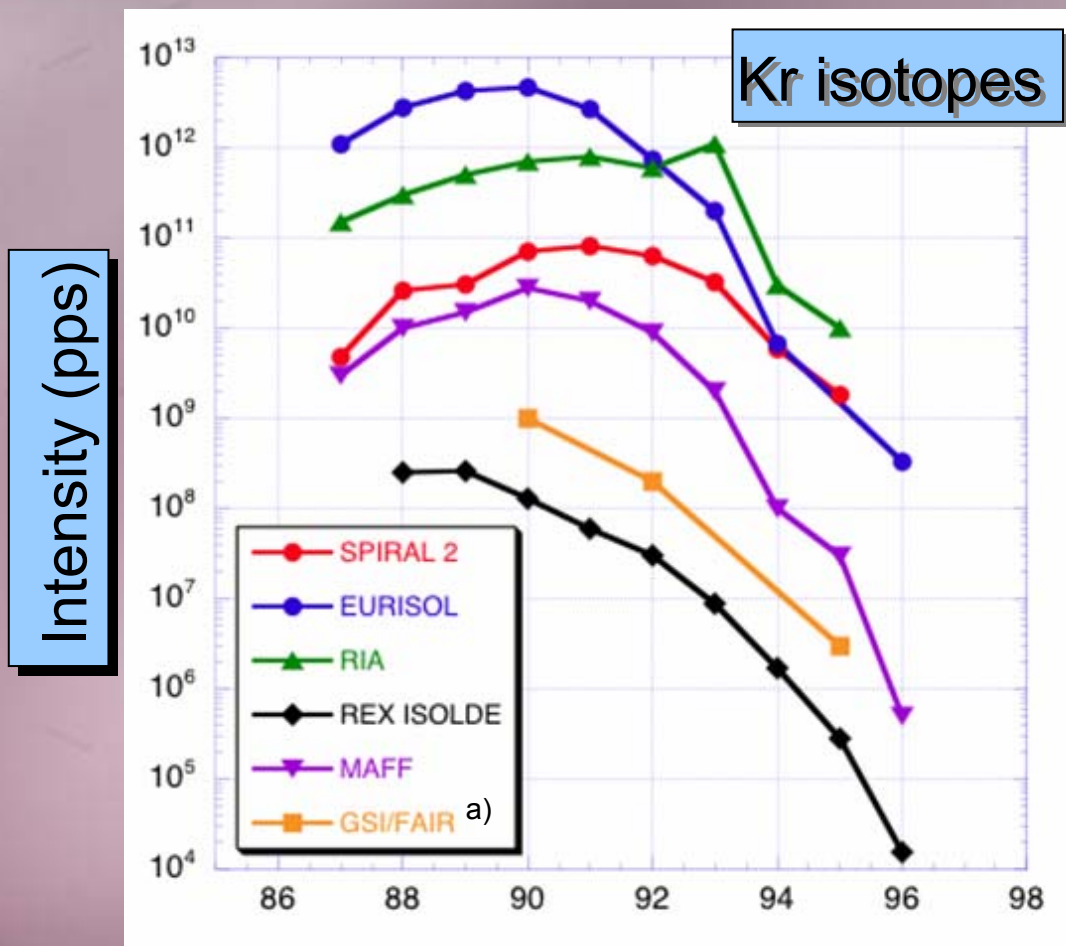
Start of Construction

1st Beam on Target (early 2011?)

## Accelerated FF Beam Intensities (pps) - Examples



*SPIRAL 2 yields for  $10^{14}$  fissions/s after acceleration compared to other RNB facilities (best numbers for all)*



a) Yield for in-flight production of fission fragments at relativistic energy

A

# Other RNB Production mechanisms

## Production of N=Z, light and heavy nuclei

p,d,HI



Thick target

Fusion-evaporation and transfer reactions  
Residues produced by thick target method  
(like at GSI mass separator)

Example:  $^{100}\text{Sn}^{1+}$

HI



Recoil Separator

Fusion-evaporation residues produced  
by thin target method (In-flight)

Ex:  $^{24}\text{Mg}(25\text{p}\mu\text{A}) + ^{58}\text{Ni} \rightarrow ^{80}\text{Zr}^{1+} 3 \times 10^4/\text{s}$

*But also:*



## Light High Intensity RNB

Isotope	A/Z	T <sub>1/2</sub> , s	Production reaction
<sup>6</sup> He	3.0	0.81	<sup>9</sup> Be(n,α) <sup>6</sup> He
<sup>8</sup> He	4.0	0.12	<sup>9</sup> Be( <sup>13</sup> C, <sup>14</sup> O) <sup>8</sup> He
<sup>8</sup> Li	2.7	0.84	<sup>11</sup> B(n,α) <sup>8</sup> Li or <sup>9</sup> Be(d, <sup>3</sup> He) <sup>8</sup> Li
<sup>9</sup> Li	3.0	0.18	<sup>11</sup> B(n, <sup>3</sup> He) <sup>9</sup> Li or <sup>9</sup> Be( <sup>7</sup> Li, <sup>7</sup> Be) <sup>9</sup> Li
<sup>11</sup> Be	2.8	13.8	<sup>11</sup> B(n,p) <sup>11</sup> Be
<sup>15</sup> C	2.5	2.45	<sup>9</sup> Be( <sup>7</sup> Li,p) <sup>15</sup> C
<sup>16</sup> N	2.3	7.13	<sup>16</sup> O(n,p) <sup>16</sup> N or <sup>10</sup> B( <sup>7</sup> Li,p) <sup>16</sup> N
<sup>18</sup> N	2.6	0.62	<sup>18</sup> O(n,p) <sup>18</sup> N
<sup>19</sup> O	2.4	26.9	<sup>19</sup> F(n,p) <sup>19</sup> O
<sup>20</sup> O	2.5	13.5	<sup>19</sup> F(n,γ) <sup>20</sup> O or <sup>19</sup> F(d,n) <sup>20</sup> O
<sup>23</sup> Ne	2.3	37.2	<sup>19</sup> F( <sup>6</sup> Li,2p) <sup>23</sup> Ne or <sup>24</sup> Mg(n,2p) <sup>23</sup> Ne
<sup>25</sup> Ne	2.5	0.60	<sup>26</sup> Mg( <sup>13</sup> C, <sup>14</sup> O) <sup>25</sup> Ne or <sup>26</sup> Mg(n,2p) <sup>25</sup> Ne
<sup>25</sup> Na	2.3	59.1	<sup>25</sup> Mg( <sup>12</sup> C, <sup>12</sup> N) <sup>25</sup> Na or <sup>25</sup> Mg(n,p) <sup>25</sup> Na
<sup>26</sup> Na	2.4	1.08	<sup>26</sup> Mg(d, <sup>2</sup> He) <sup>26</sup> Na or <sup>26</sup> Mg(n,p) <sup>26</sup> Na

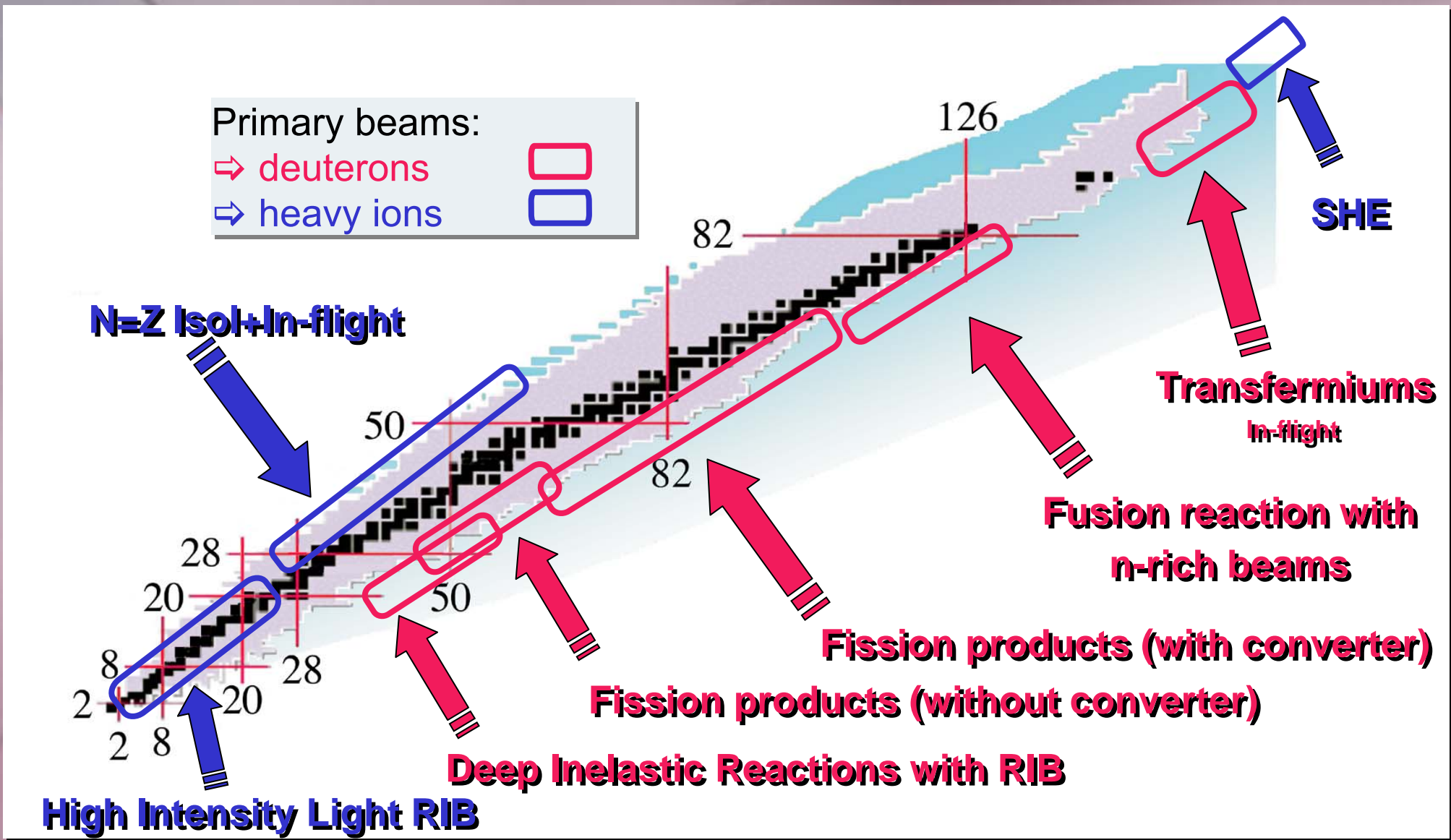
Halo  
Nuclei

Isotope	A/Z	T <sub>1/2</sub> , s	Production reaction
<sup>8</sup> B	1.6	0.77	<sup>12</sup> C(p,αn) <sup>8</sup> B
<sup>10</sup> C	1.7	19.3	<sup>11</sup> B(p,2n) <sup>10</sup> C
<sup>11</sup> C	1.8	1224	<sup>11</sup> B(p,n) <sup>11</sup> C or <sup>14</sup> N(p,α) <sup>11</sup> C
<sup>13</sup> N	1.9	598	<sup>12</sup> C(d,n) <sup>13</sup> N or <sup>13</sup> C(p,n) <sup>13</sup> N
<sup>14</sup> O	1.8	70.6	<sup>14</sup> N(d,2n) <sup>14</sup> O or <sup>14</sup> N(p,n) <sup>14</sup> O
<sup>15</sup> O	1.9	122	<sup>14</sup> N(d,n) <sup>15</sup> O or <sup>15</sup> N(p,n) <sup>15</sup> O
<sup>17</sup> F	1.9	64.5	<sup>16</sup> O(d,n) <sup>17</sup> F or <sup>14</sup> N(α,n) <sup>17</sup> F
<sup>18</sup> Ne	1.8	1.67	<sup>19</sup> F(p,2n) <sup>18</sup> Ne
<sup>19</sup> Ne	1.9	17.3	<sup>19</sup> F(p,n) <sup>19</sup> Ne
<sup>21</sup> Na	1.9	22.4	<sup>19</sup> F( <sup>3</sup> He,n) <sup>21</sup> Na
<sup>27</sup> Si	1.9	4.16	<sup>27</sup> Al(d,2n) <sup>27</sup> Si
<sup>35</sup> Ar	1.9	1.77	<sup>35</sup> Cl(p,n) <sup>35</sup> Ar

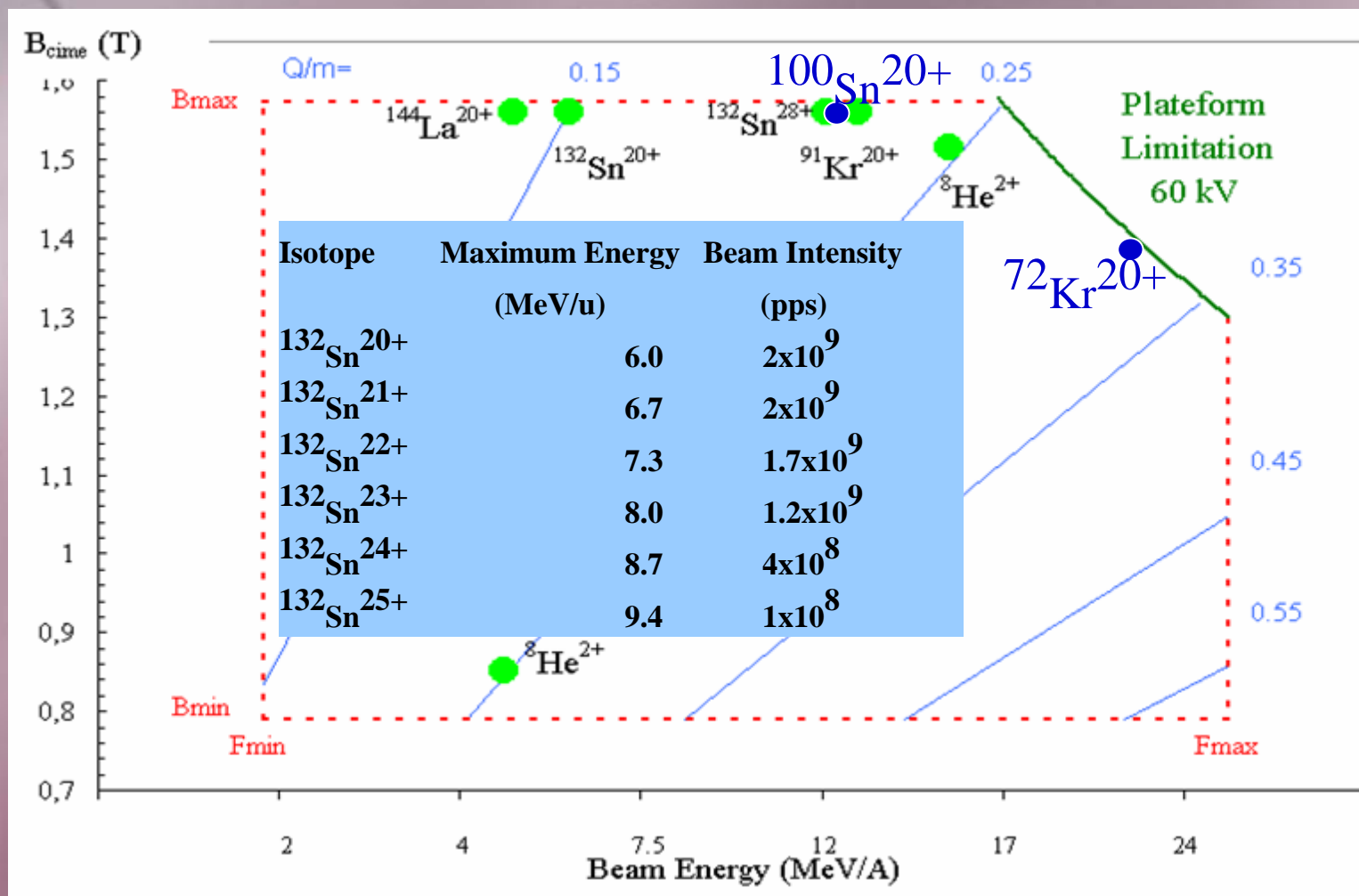
In-target (1liter volume) production yields:

$${}^9\text{Be}(n,\alpha){}^6\text{He} \sim 10^{13} \text{ pps}$$

$${}^{14}\text{N}(d,n){}^{15}\text{O} \sim 10^{12} \text{ pps}$$



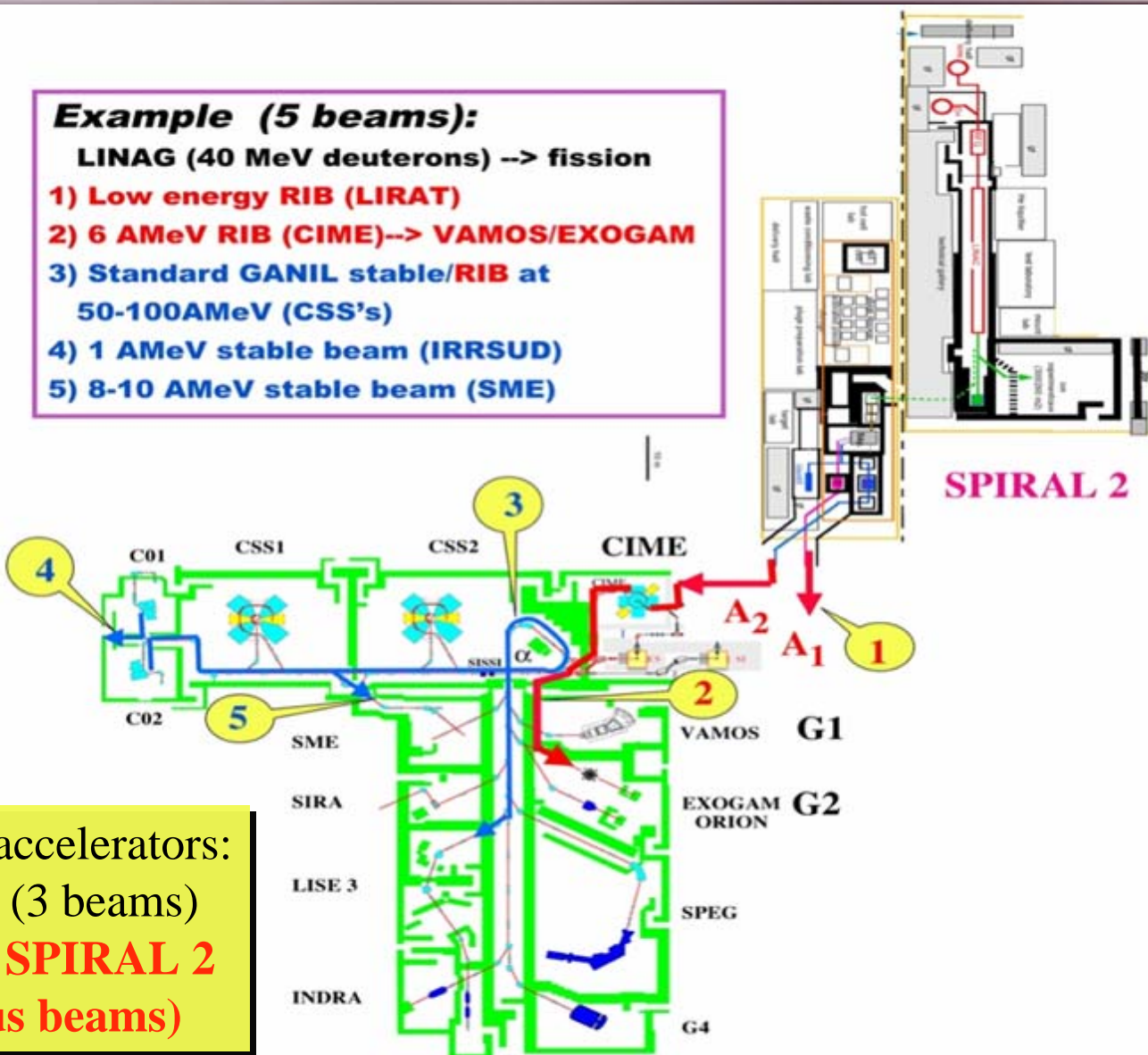




**Example (5 beams):**

**LINAG (40 MeV deuterons) --> fission**

- 1) Low energy RIB (LIRAT)
- 2) 6 AMeV RIB (CIME)--> VAMOS/EXO GAM
- 3) Standard GANIL stable/RIB at 50-100 AMeV (CSS's)
- 4) 1 AMeV stable beam (IRRSUD)
- 5) 8-10 AMeV stable beam (SME)



Operation of the accelerators:  
 66 weeks today (3 beams)  
**120 weeks with SPIRAL 2**  
**(5 simultaneous beams)**

✓ **SPIRAL 2 Workshops:**

- **Neutrons for science at SPIRAL 2 (Ridikas, Heil): GANIL, 13-14/12/2004**
- **Physics with separated low energy beams at SPIRAL2 (Blank, Naviliat): GANIL, 4-5/07/2005**
- **Future prospects for high resolution gamma spectroscopy at GANIL (Korten, Wadsworth): GANIL, 4-6/10/2005**
- **Nuclear Astrophysics with SPIRAL2 (Sorlin, Langanke): GANIL, 17-18/10/2005**
- **SPIRAL2 Reactions (Blumenfeld, Catford) : GANIL, 19-21/10/2005**

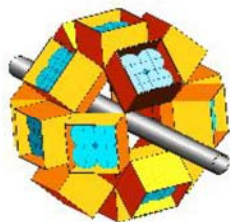
**All information and reports on: [www.ganil.fr](http://www.ganil.fr)**

- ✓ **Establish strong international collaborations in charge of the development of new equipment or improvements of the existing detectors**
  - Letters of intent - few weeks after the Workshop
  - Proposals to be submitted in 2006-2007
- ✓ **Detailed examination of the SPIRAL 2 performances by the physics community**
  - Propose moderate-scale improvements and future extensions
- ✓ **Establish synergies with FAIR/NUSTAR, EURISOL, EURONS**

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# Goals of the Workshops

EXO GAM



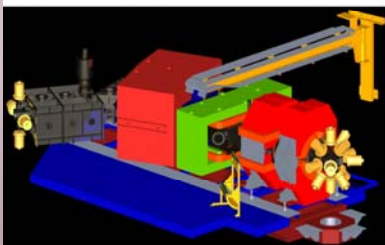
ORION



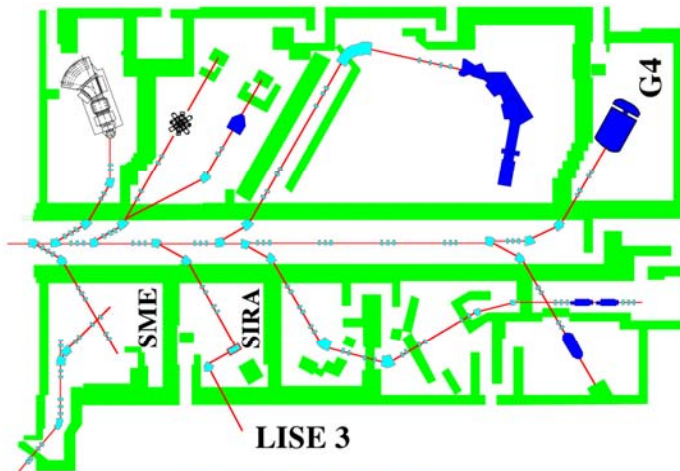
SPEG



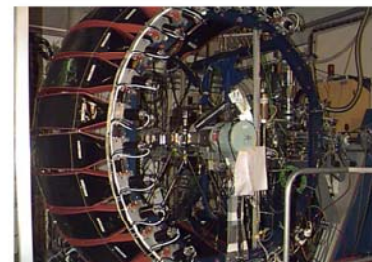
VAMOS



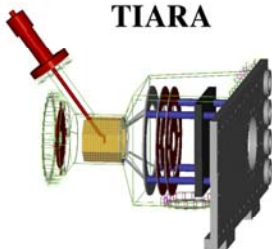
MUST



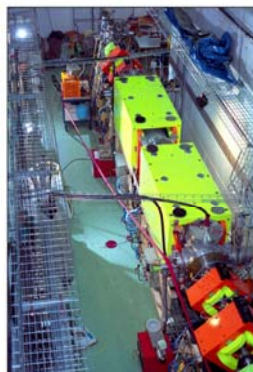
TONNERRE



TIARA



LISE 3



INDRA



+ MUST2, DIAMANT  
DEMON, n-Wall  
Château de Cristal  
MAYA...

**Existing GANIL Accelerators**

**CIME Cyclotron**  
Acceleration of RI Beams  
 $E < 25$  AMeV

**Existing GANIL**  
Exp. Area: EXOGAM,  
AGATA etc.

**Low energy RNB**  
(LIRAT) traps, decay  
spectroscopy etc.

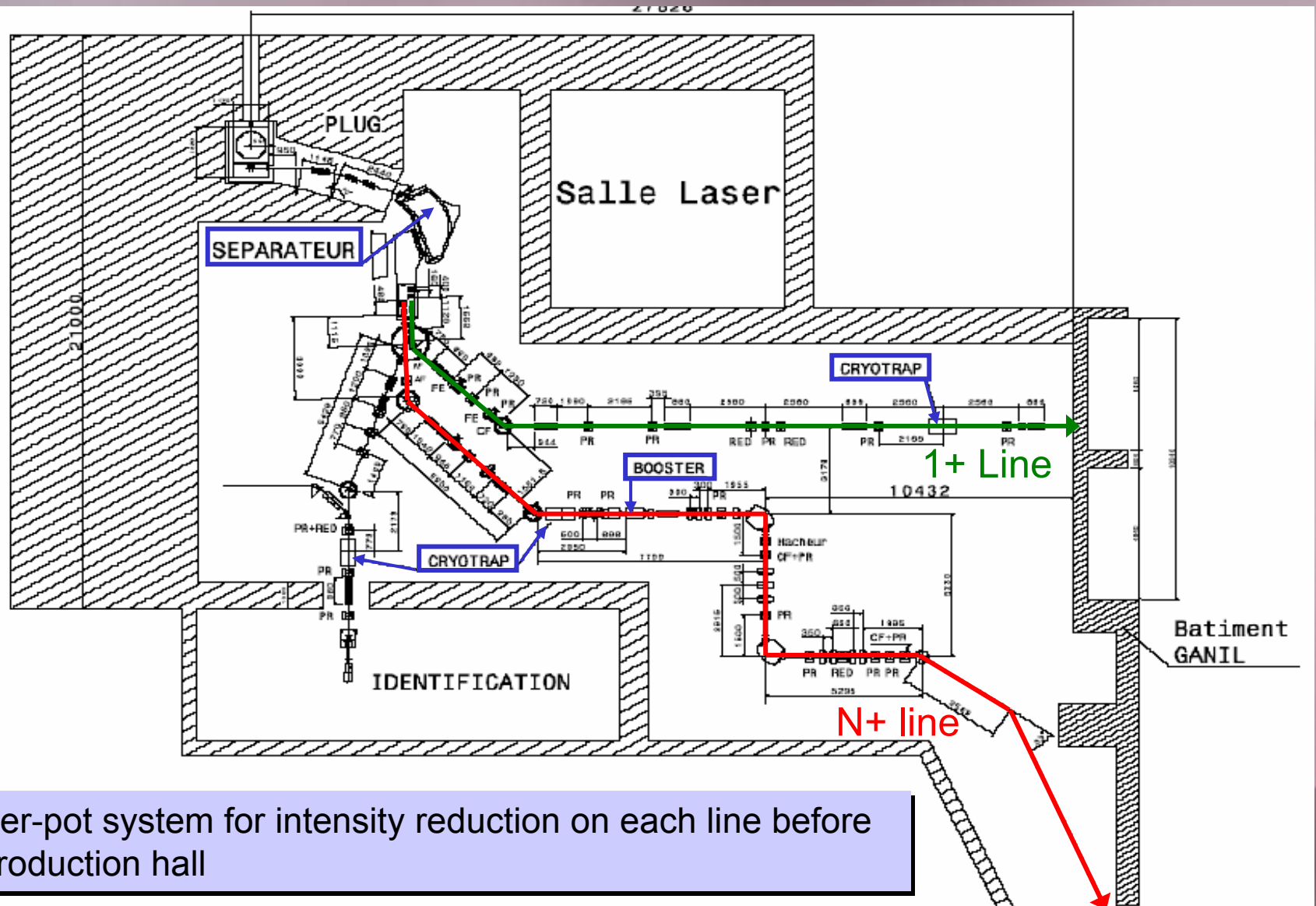
**Obvious common topics:**  
Neutron detectors  
Fast Timing  
TAS  
Moments  
AGATA  
Charged particle det.  
Plunger  
Magnetic spectrometer  
Electr. & DAQ

**Stable Heavy-Ion Exp. Hall**  
New spectrometer for high-  
intensity stable-ion beams

**Superconducting LINAC**  
 $E = 14.5$  AMeV, 1mA for heavy Ions  $A/q=3$   
 $E = 40$  MeV, 5mA for deuterons



# Beam-line Implementation (Brama)



+ multi-pepper-pot system for intensity reduction on each line before exiting the production hall