LNS Users' Group Meeting

16 June 2010

^{252}Cf @ LNS

Exotic beam production

By a new source for the CS

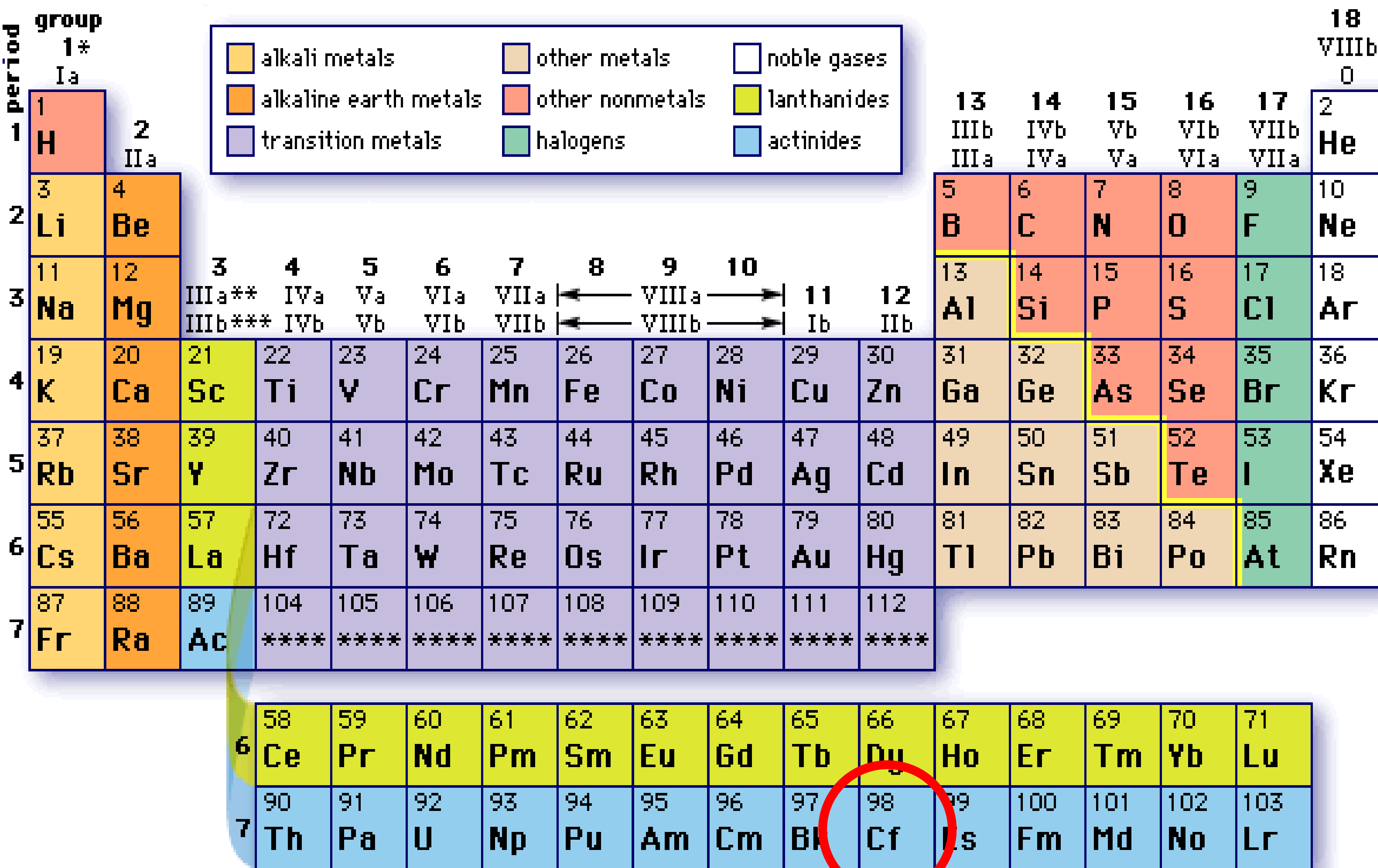
S.Pirrone, INFN-Sezione di Catania

Outline

^{252}Cf properties

^{252}Cf @ATLAS

^{252}Cf @LNS



* Numbering system recommended by the International Union of Pure and Applied Chemistry (IUPAC)

** Previous IUPAC numbering system

*** Numbering system recommended by the Chemical Abstracts Service

**** For the names of elements 104–112, see table.

^{252}Cf –Production

n – irradiation of transuranic elements

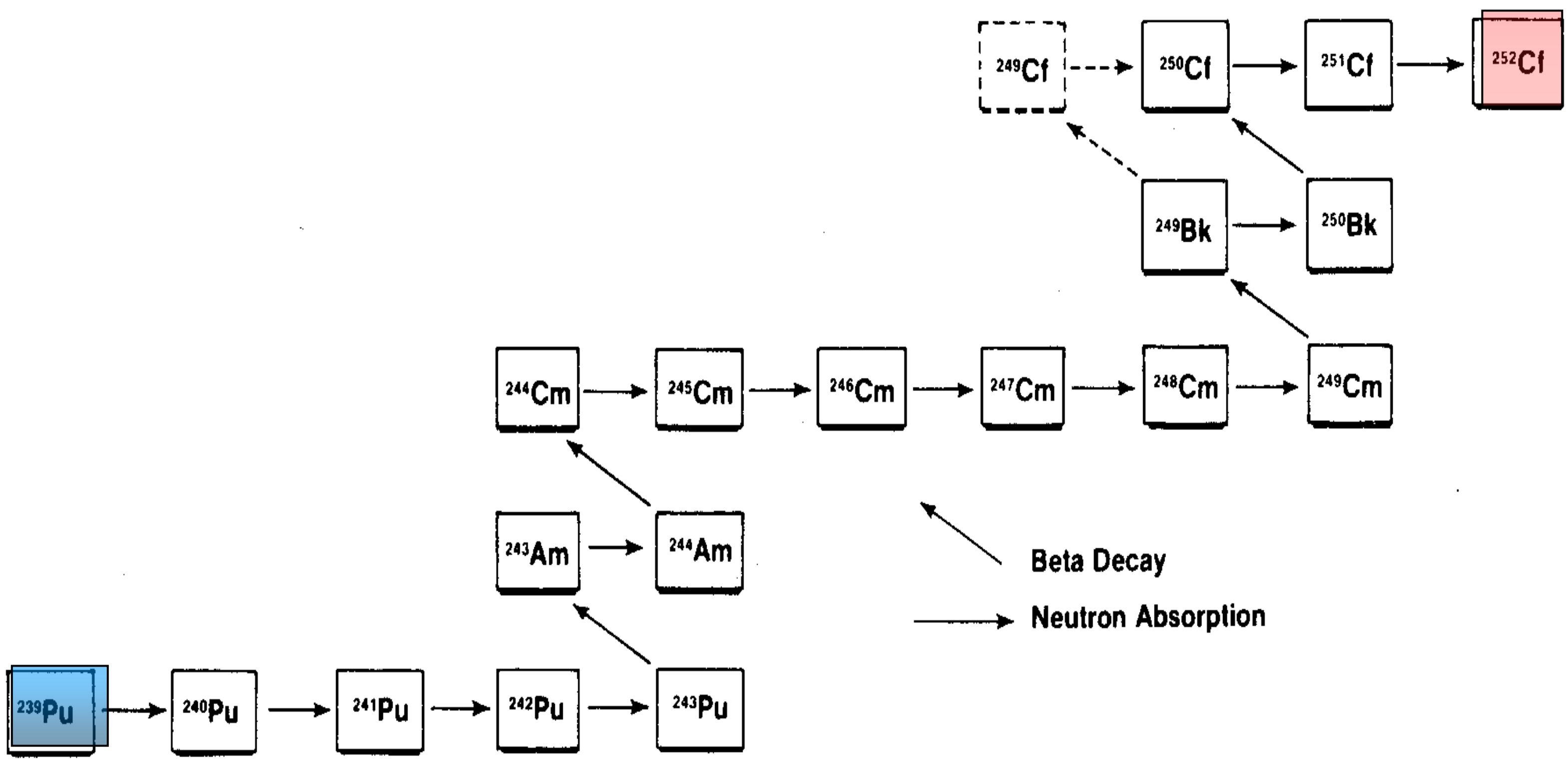


Fig. 26.1. Diagram Showing the Production of ^{252}Cf.

^{252} Cf - decay

$$97\% \quad \alpha + {}^{248}_{96}Cm + 6\,MeV$$

$$^{252}_{98}Cf$$

$$Half-life = 2.645\ years$$

$$3\% \quad fission\ products + 3.8\,n\,/\,fission + 185\,MeV$$

Half-life (effective):	2.65 years
Half-life (spontaneous fission):	85.5 years
Half-life (α-decay):	2.73 years
Neutron emission:	$2.3 \cdot 10^{12}$ neutrons/s per gram
Average neutron energy:	2 MeV
Specific activity:	$2.0 \cdot 10^{13}$ Bq per gram

~500 Ci per gr , **1Ci = 2 mgr**

^{252}Cf - Energy Spectrum

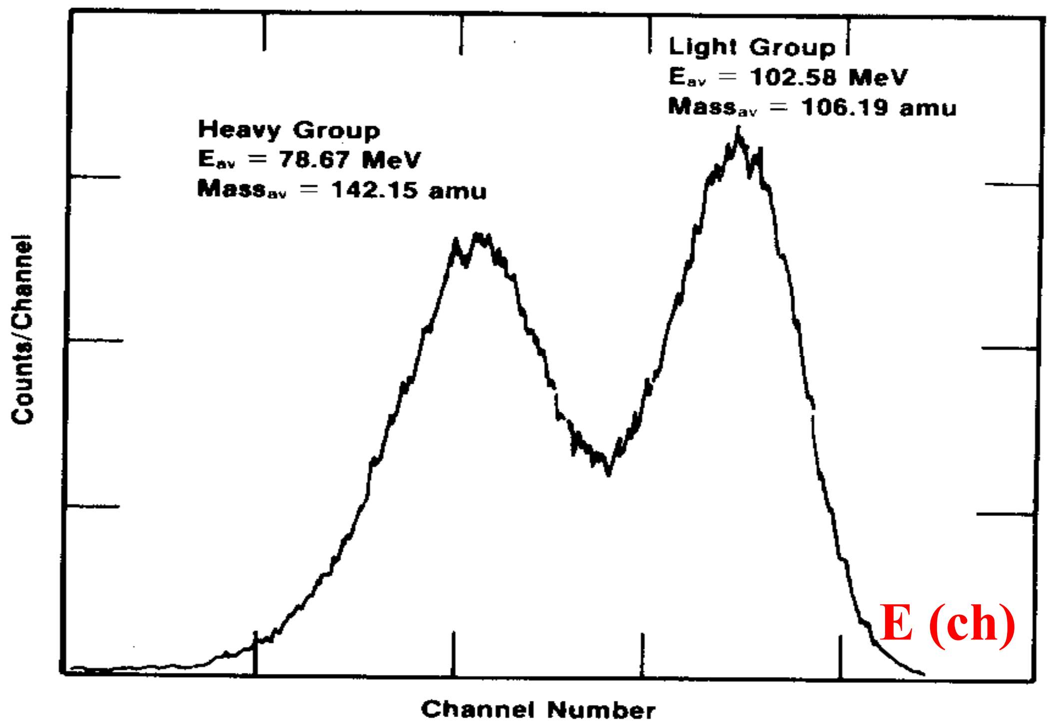


Fig. 26.2. Typical Pulse Height Spectrum for a Thin ^{252}Cf Fission Foil Source.

Fragment	Energy
Light $^{106}_{46}Pd$	102.58
Heavy $^{142}_{60}Nd$	78.67

^{252} Cf – FF Mass distribution

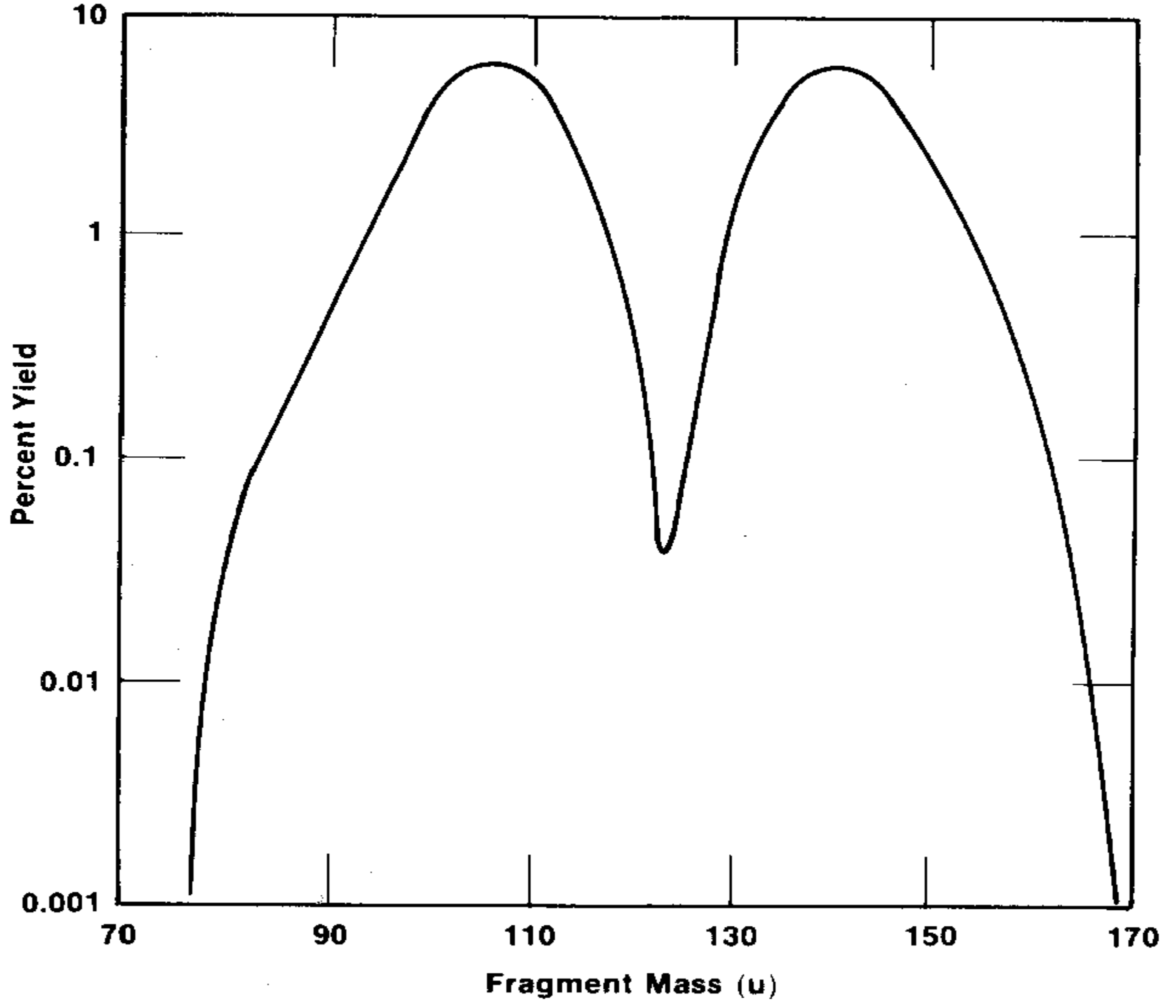
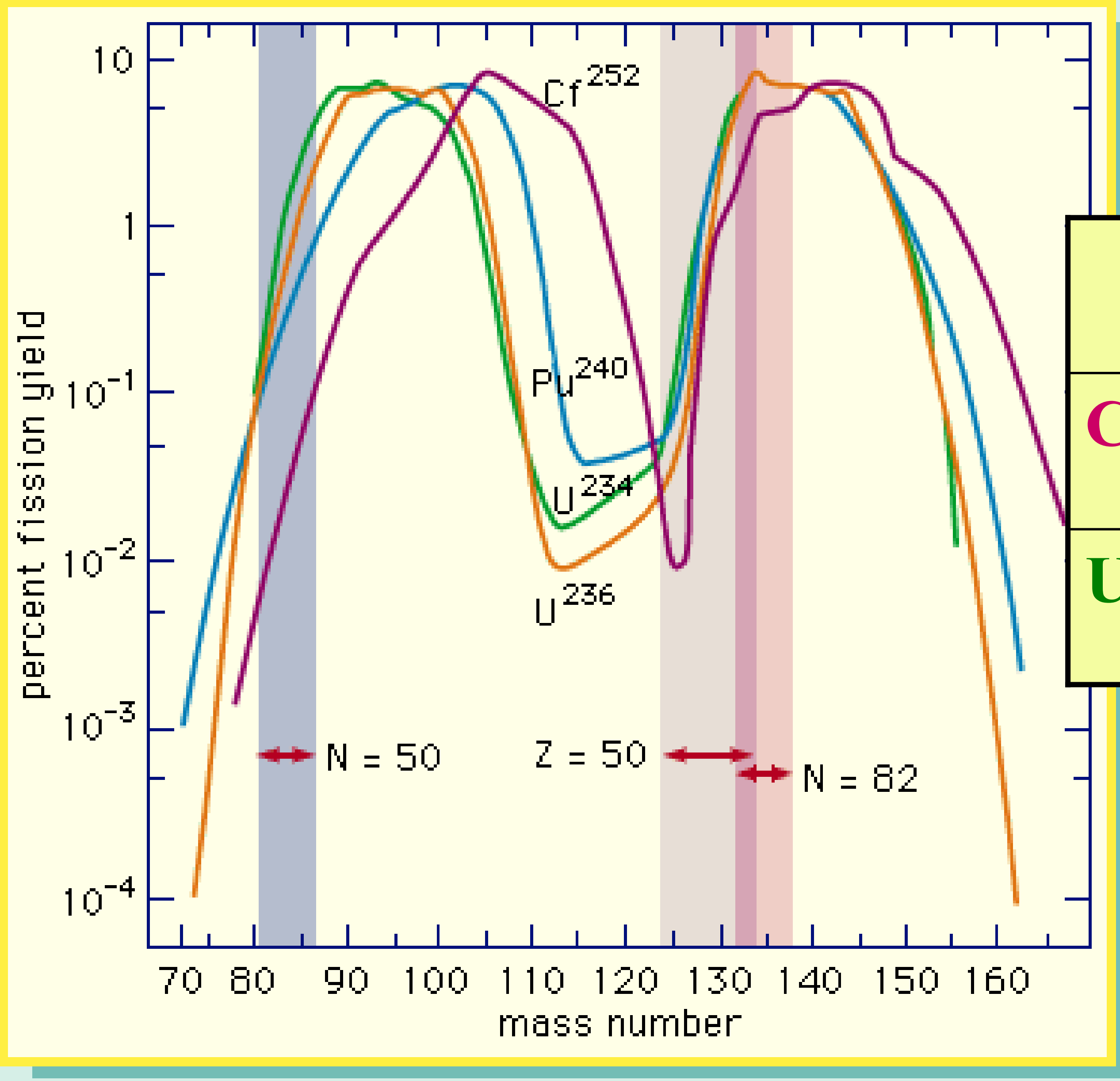
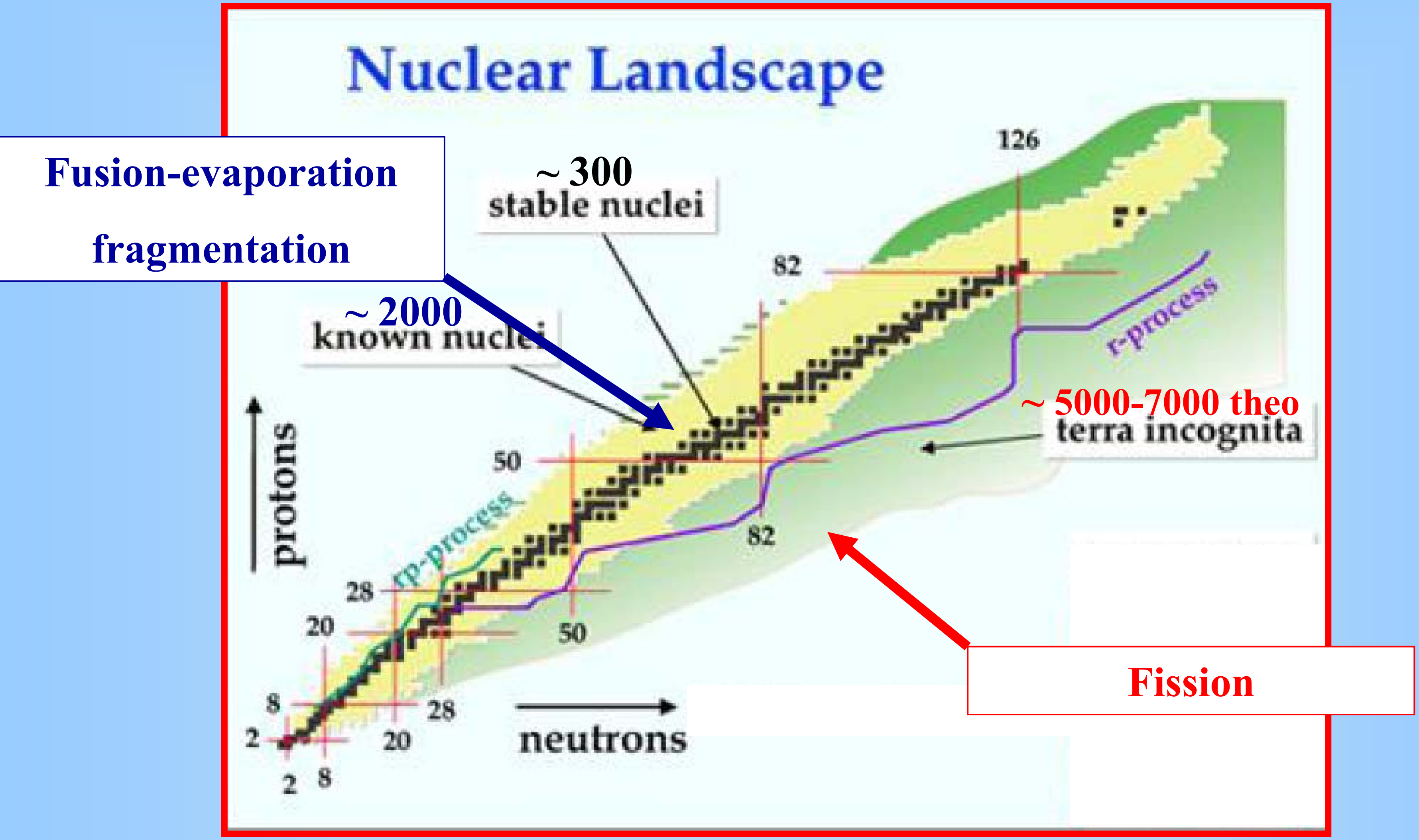


Fig. 26.4. Mass Distribution of Fission Fragments for ^{252}Cf.

FF Mass distributions –Comparison



	Z1	A1	Z2	A2
Cf	45	105	60	140
U	40	90	55	135



n-rich region : next frontier, exploration has started (HRIBF) and new facilities are under construction

(RIA , SPIRAL2-GANIL, SPES-LNL….)

hribf

Holifield Radioactive Ion Beam Facility
Oak Ridge National Laboratory

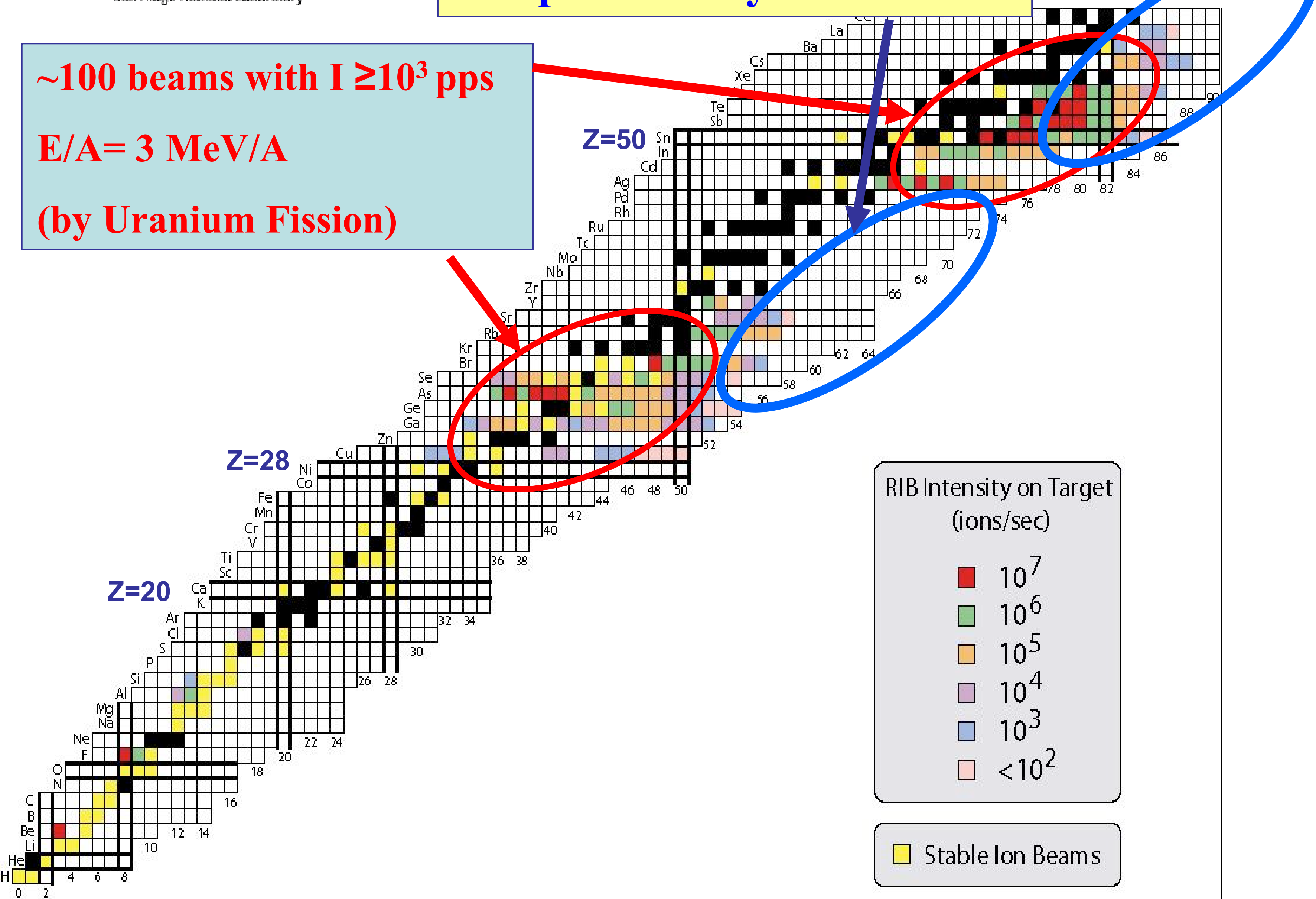
^{252}Cf fission

Provides unique beams complementary to HRIBF

~100 beams with I ≥10^3 pps

E/A= 3 MeV/A

(by Uranium Fission)



^{252}Cf @ ATLAS (Argonne) - Source Upgrade

- Commercial Source produced by Oak Ridge (15-20 K$)

- Produced of the required strength in various forms.

- Obtained by electrodeposit on a thick tantalum backing (s= 2.5 mm).

  1 Ci = 3.7×10^{10} Bq

  Ø = 5cm

  ρ = 51 mCi/cm^{2-}

-Covered by a

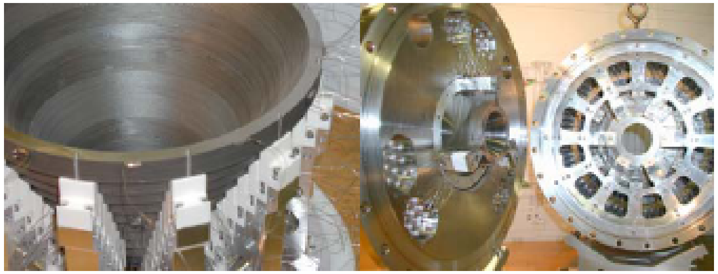
  2 mg/cm^2 , Au foil

located 1mm above the source for protection and confinement.

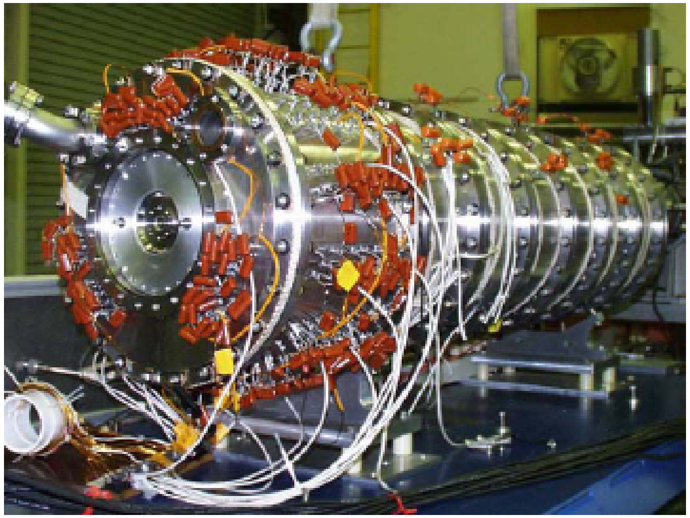
It will enclose the source, except for a pumping hole to equilibrate pressure inside the trapped volume with the gas catcher pressure

New opportunity: ^{252}Cf source + large gas catcher as neutron-rich isotope source

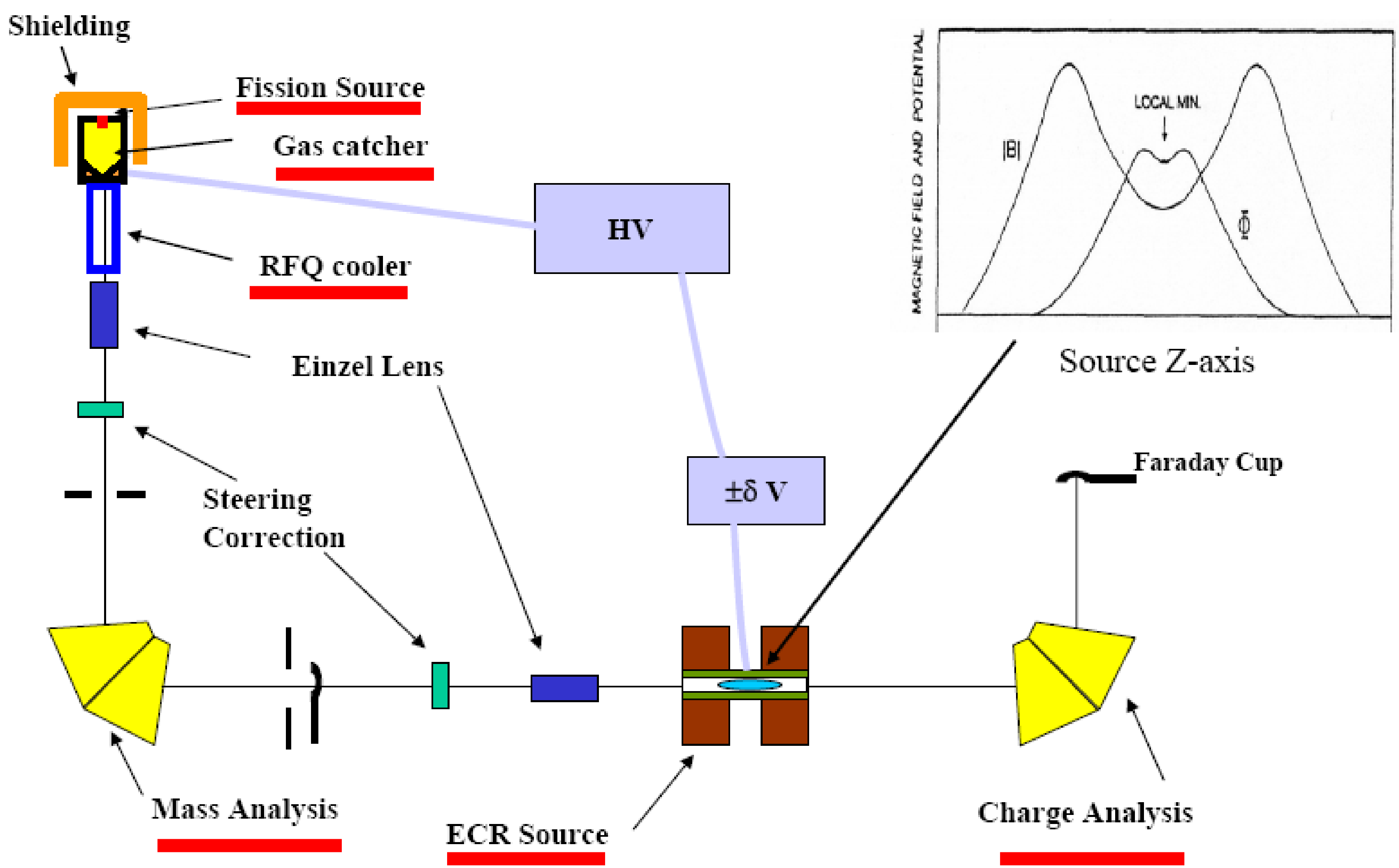
- Shortened version of RIA gas catcher can efficiently stop fission products from a fission source
  - ~ 50% stopped in gas for backed source
- About 45% of those can be extracted as charged ions
- Very efficient and fast source, provides cooled bunched beams for post-acceleration
- Production peaks in new regions and extraction is element independent … new isotopes available



Gas catcher technology developed, tested and now routinely used at ATLAS for CPT and RIA programs

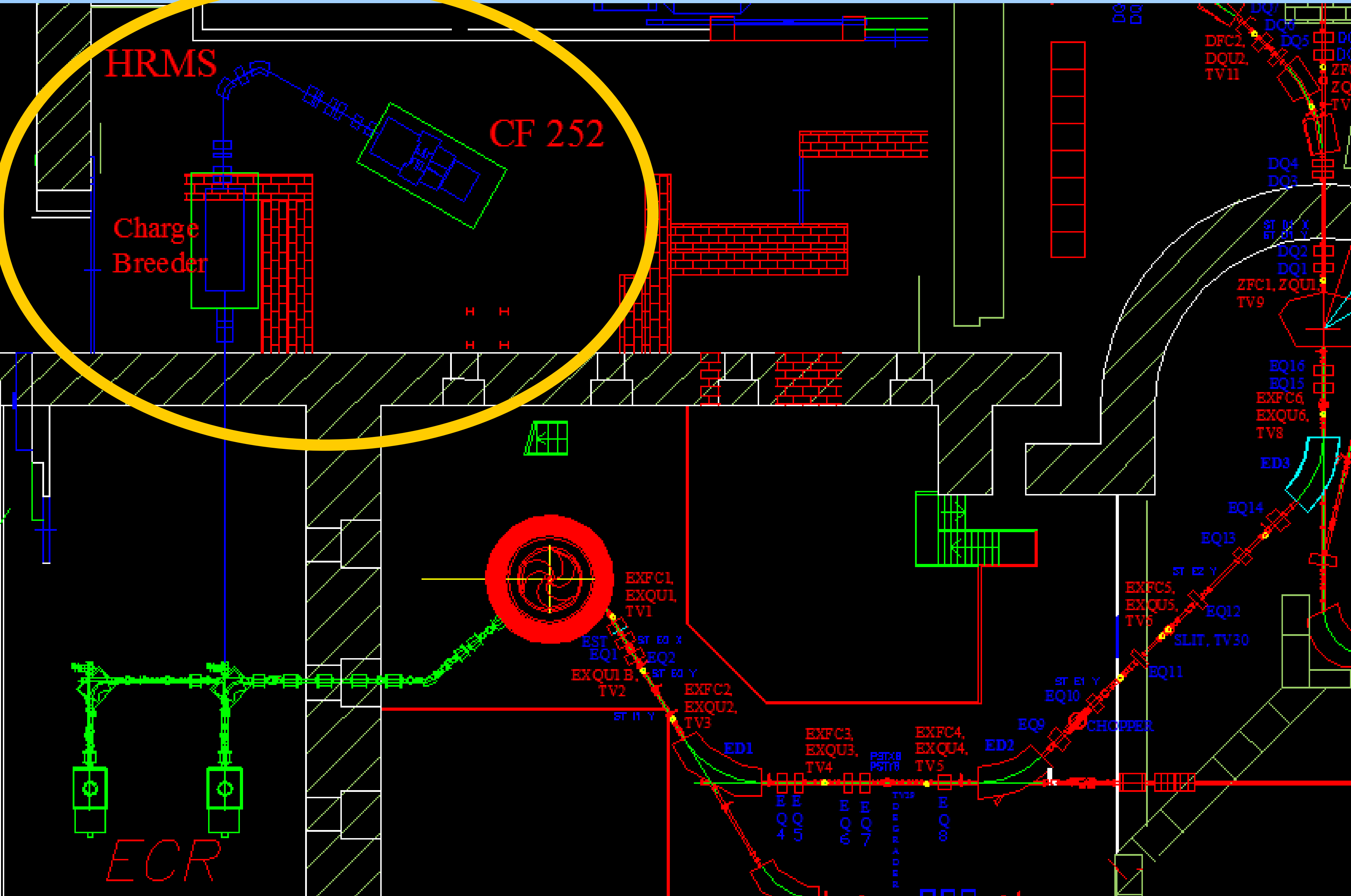


Proposed Charge-Breeder Scheme



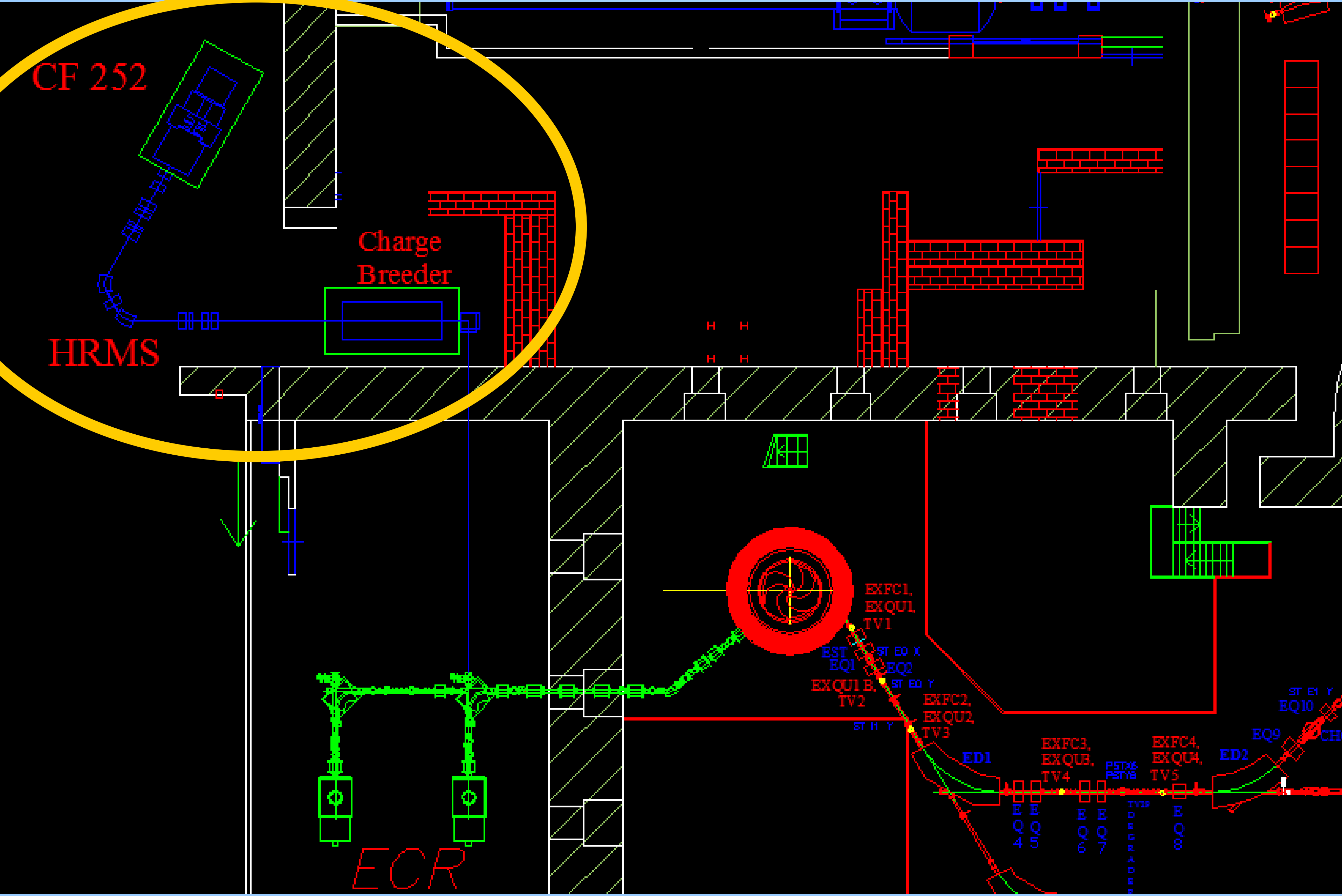
252 Cf @LNS (sol.1)

By L.Calabretta



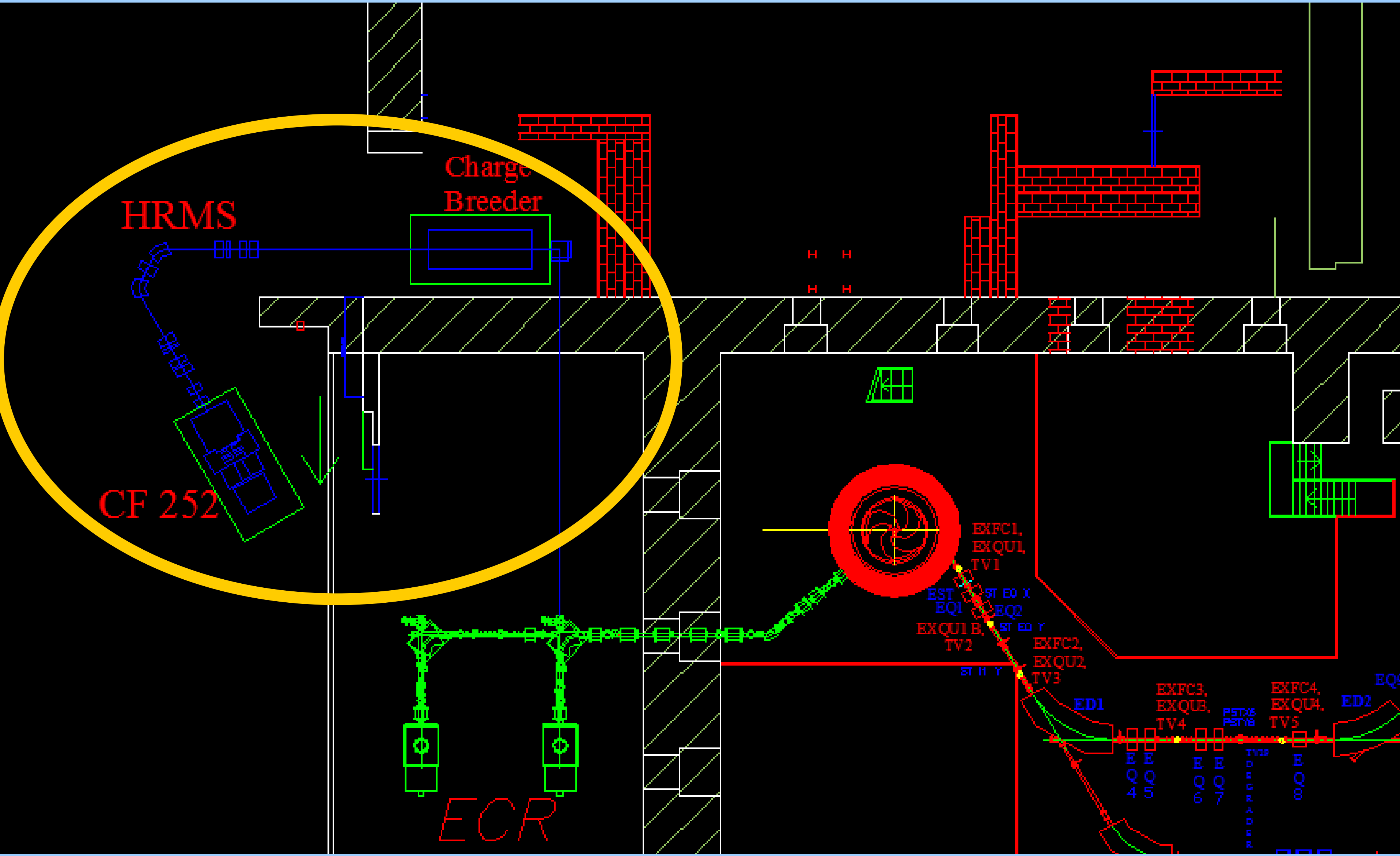
252 Cf @LNS (sol.2)

By L.Calabretta



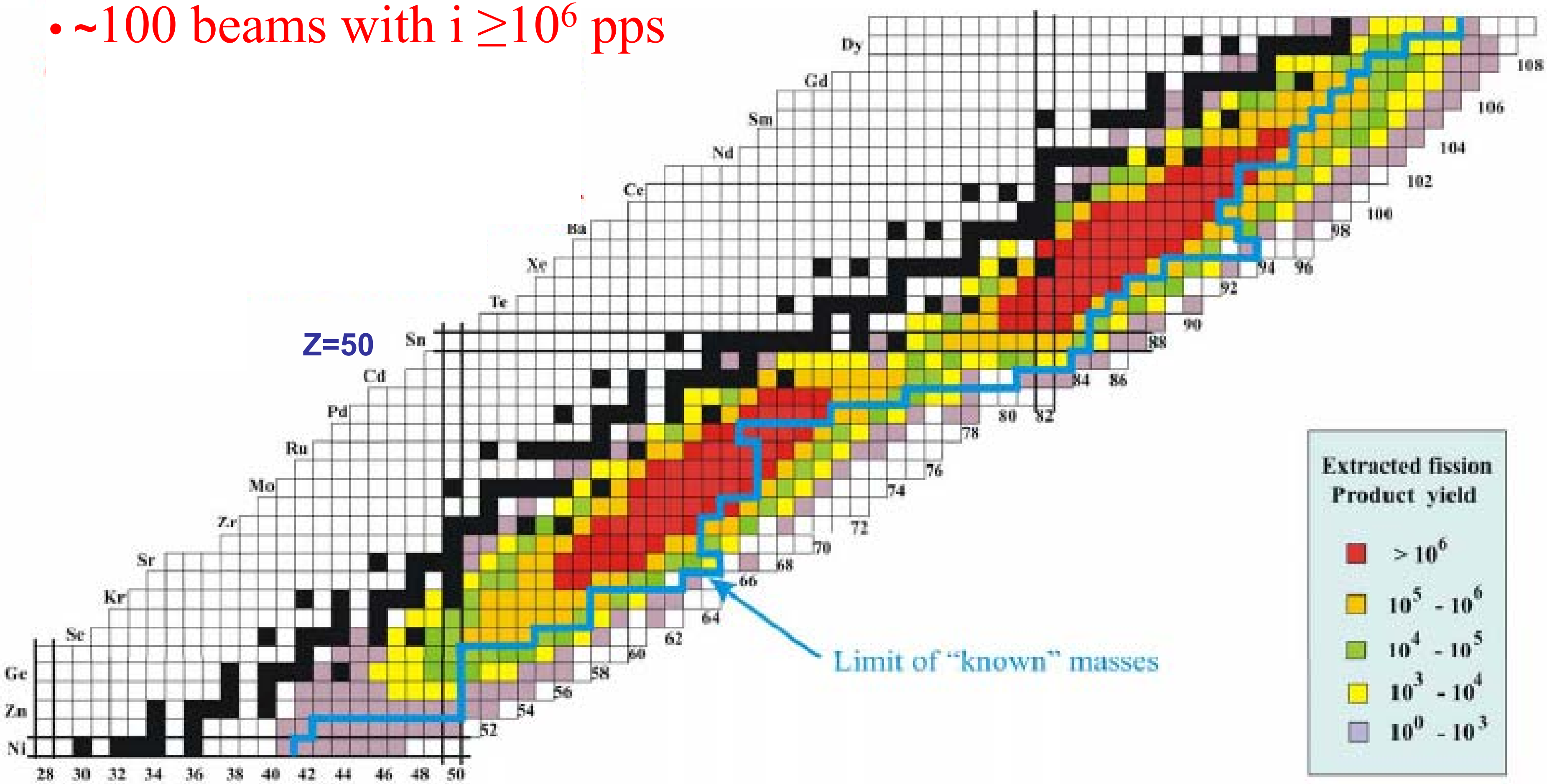
252 Cf @LNS (sol.3)

By L.Calabretta



Extracted isotope yield at low energy @ATLAS

- 1 Ci ^{252}Cf source
- ~100 beams with i $\geq 10^6$ pps



Examples of Yields for Representative Species

Calculated maximum beam intensities for a 1 Ci ^{252}Cf fission source using expected efficiencies.

Isotope	Half-life (s)	Low-Energy Beam Yield (s^{-1})	Accelerated Beam Yield (s^{-1})	LNS
^{104}Zr	1.2	6.0×10^5	2.1×10^4	0.4×10^4
^{143}Ba	14.3	1.2×10^7	4.3×10^5	0.8×10^5
^{145}Ba	4.0	5.5×10^6	2.0×10^5	0.4×10^5
^{130}Sn	222.	9.8×10^5	3.6×10^4	0.7×10^4
^{132}Sn	40.	3.7×10^5	1.4×10^4	0.3×10^4
^{110}Mo	2.8	6.2×10^4	2.3×10^3	0.6×10^3
^{111}Mo	0.5	3.3×10^3	1.2×10^2	0.24×10^2
$^{92-94}Kr$	1- 4	3×10^5	2×10^4	0.5×10^4

~65 species have accelerated intensities of over 10^5

>150 additional species have accelerated intensities of over 10^4

By L.Calabretta

ATLAS Project planning

Cost - 5 M$

Manpower - 10.5 man year

Realization Time - 2 years

@LNS , we need (by L.Calabretta)

Restyle the CS central region to get the injection of accelerated beams at 50-60 kV (now possible up to 30 kV)

Increase the injection line transmission efficiency (the higher energy help us to do this!)

Search of ^{252}Cf source manufacter in Europe

Contact to Oak- Ridge

Contact to ATLAS to buy the GAS Catcher, the RFQ-cooler and the Charge Breeder

@ATLAS E=10-15 MeV/A

Important physics questions

- **modification of nuclear structure in neutron rich systems**
  - *shell-structure quenching*
  - *single particle structure near n-rich magic nuclei*
  - *pairing interaction in weakly bound systems*
- **collective behavior in neutron-rich systems**
- **r-process path**
  - *ground-state information*
    - mass
    - lifetime
    - beta-delayed neutron branching ratio
  - *neutron capture rate*
  - *fissionability of very heavy n-rich isotopes*

@LNS E = 8-25 MeV/A

Important Physics Questions

- ***EoS of Asymmetric nuclear matter***
  - ***Density dependence of Symmetry Energy***

    $\rho<\rho_0$ ***nuclear structure, astrophysical problems ,***
    (neutron star crust, …)

- ***Nuclear structure and properties of n-rich systems***
  - ***Neutron skin***
  - ***Pigmy dipole (PDR)***
  - ***GDR, GMR in n-rich nuclei***

- ***Isospin Phisics and reaction mechanism***
  - ***time scaling***
  - ***fission reaction***
  - ***fusion reaction***
  - ***dynamical dipole (DDR)***
  - ***neck dynamics***
  - ***N/Z equilibration***

in collaboration with M.Colonna

Conclusions

- This project would allow the production of unique exotic beams at Intermediate energy in a "reasonable" time.

- It will keep LNS competitive in radioactive beam delivering.

- It will increase the techniques and expertise necessary to explore n-rich region

- This project has to be seen in synergy with SPES @LNL (preparatory , common tecnological development)

-It has to be well compared with the possibility to get exotic beams by *Fragmentation in Flight* technique with heavy primary projectile

(CHIMERA group in next experiments @LNS)

<u>Working group</u> – March 2010

C.Agodi (INFN-LNS)

R.Alba (INFN-LNS)

L.Calabretta (INFN-LNS)

F.Cappuzzello (INFN-LNS)

G.Cardella (INFN-Catania)

M.Colonna (INFN_LNS)

G.Cuttone (INFN-LNS)

I.Lombardo (INFN-LNS and University of Catania)

G.Prete (INFN-LNL)

U.Schroeder (University of Rochester, USA)

S.P. (INFN-Catania)

…….