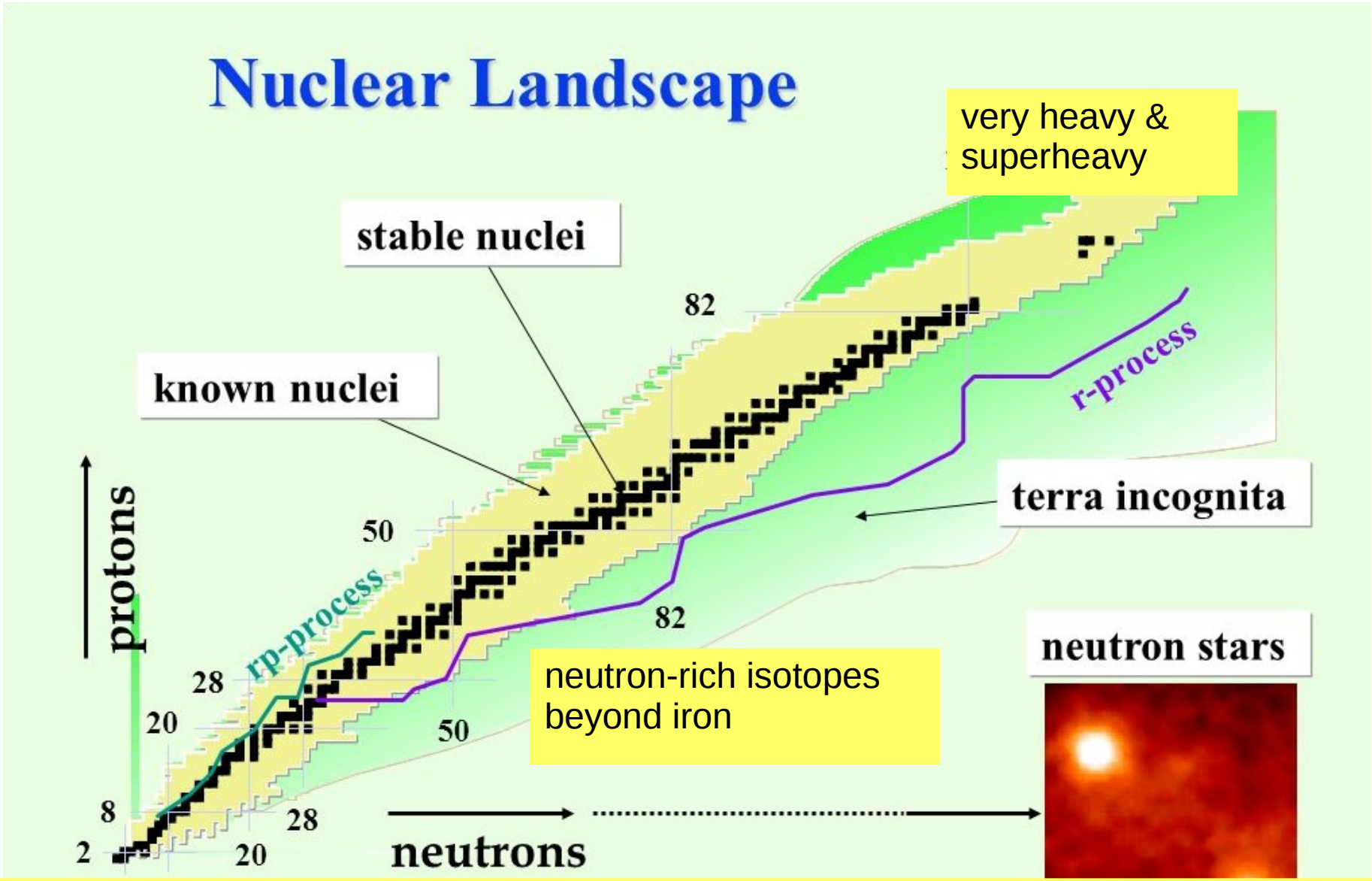
Charting Terra Incognita of Exotic Nuclei

S Franchoo, IPN Orsay

E Minaya Ramirez, D Yordanov, IPN Orsay
C Gaulard, A Lopez-Martens, CSNSM Orsay
A Drouart, B Sulignano, Irfu/SPhN Saclay

technical coordinator A Said, IPN Orsay



Beta decay cannot rule out the existence of isomers or alternative spin assignments, leaving doubt on the level scheme that is obtained. Only the measurement of masses, spins and moments can solve this (m, J^{π}, δr^2, μ, Q)

Terra Incognita

Alto transnational-access user facility

200 users /y

Stable beams 2500 h /y

25% light ion beams

75% heavy ion beams

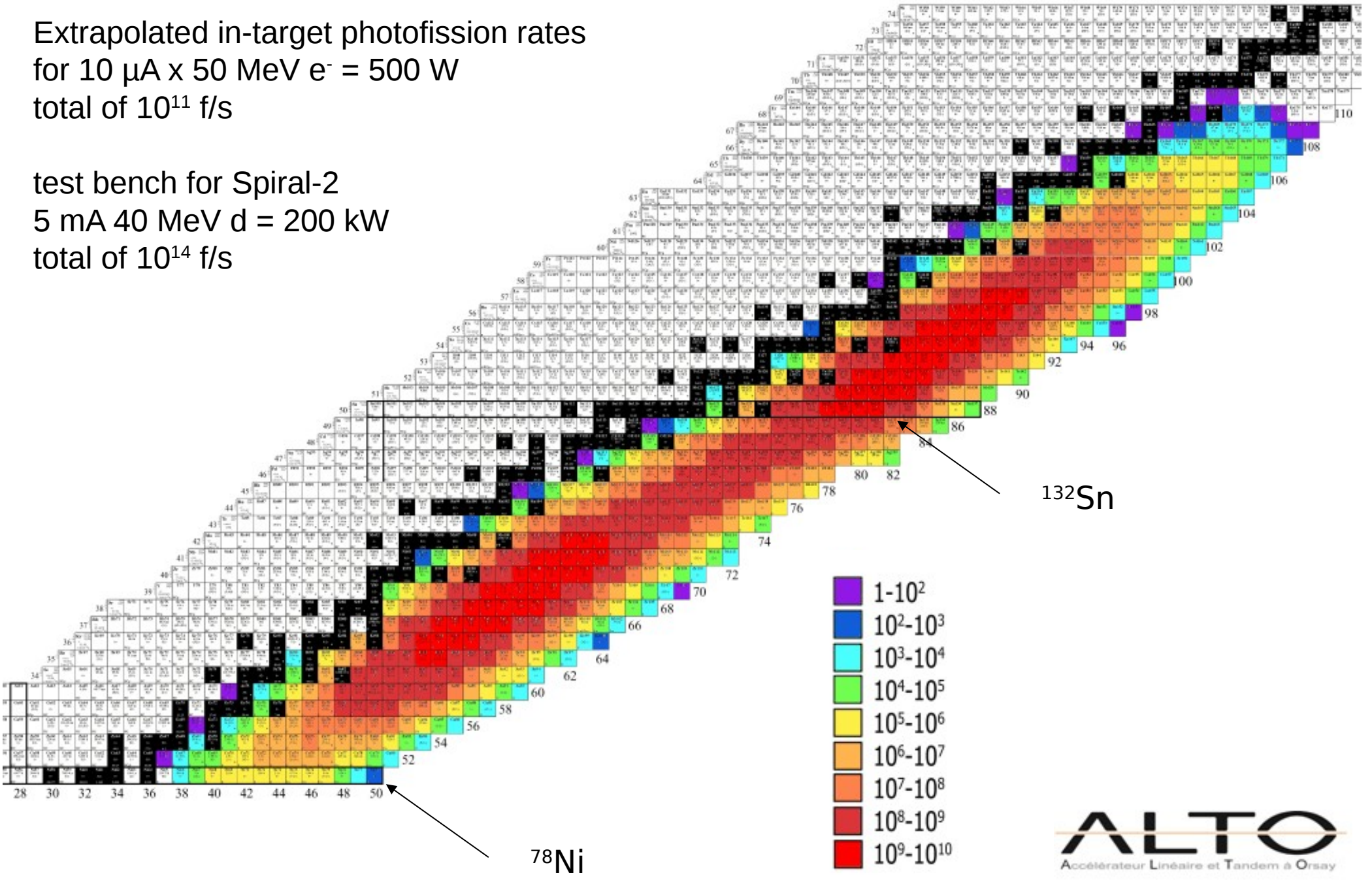
Radioactive beams 100 h /y (2016)

ALTO
Accélérateur Linéaire et Tandem à Orsay

Terra Incognita

Extrapolated in-target photofission rates
for 10 µA x 50 MeV e^- = 500 W
total of 10^{11} f/s

test bench for Spiral-2
5 mA 40 MeV d = 200 kW
total of 10^{14} f/s



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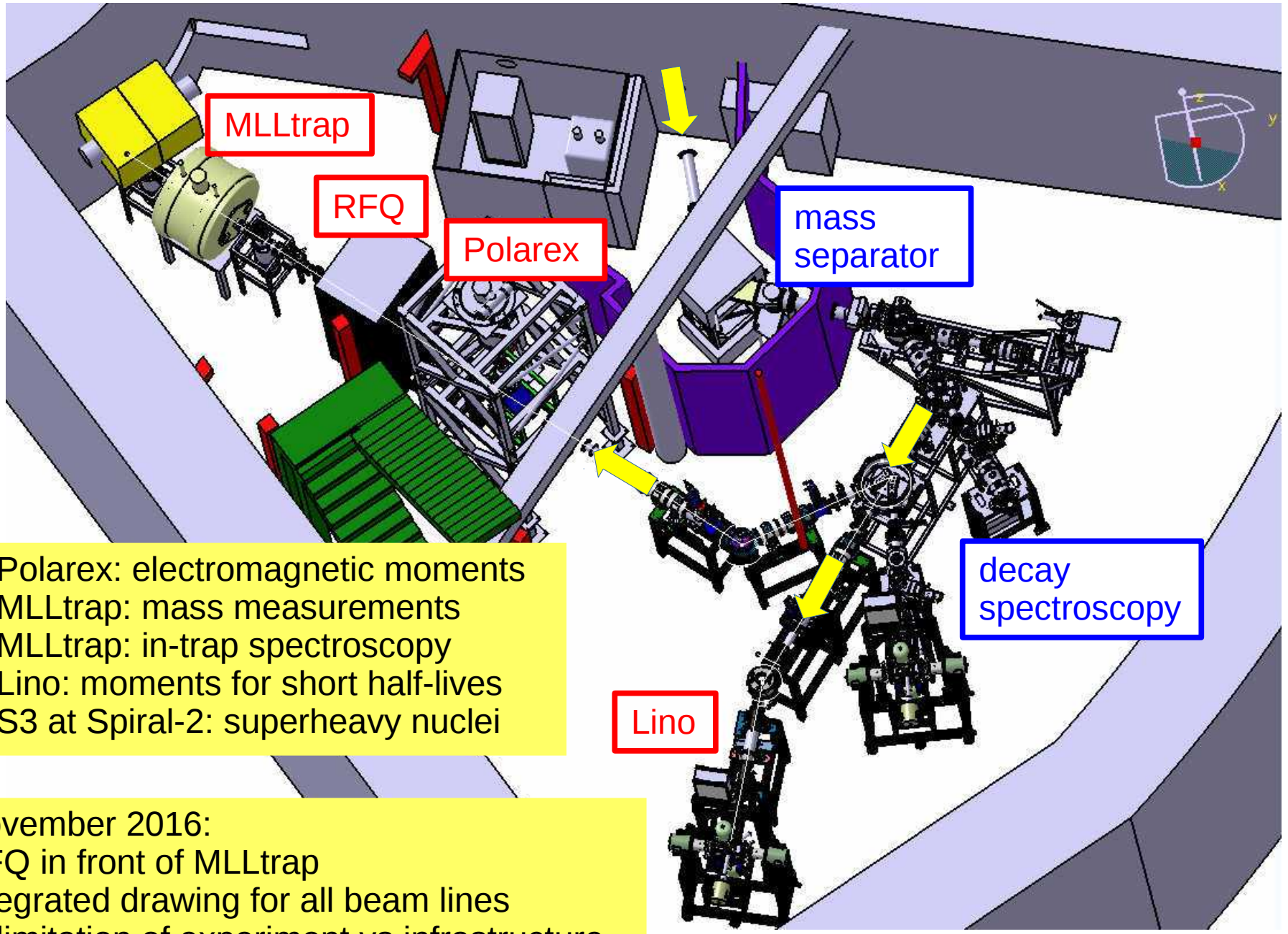
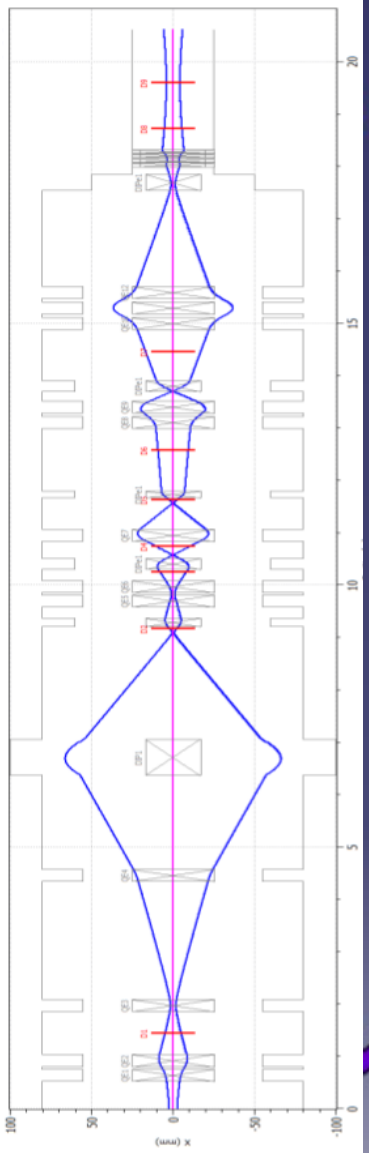
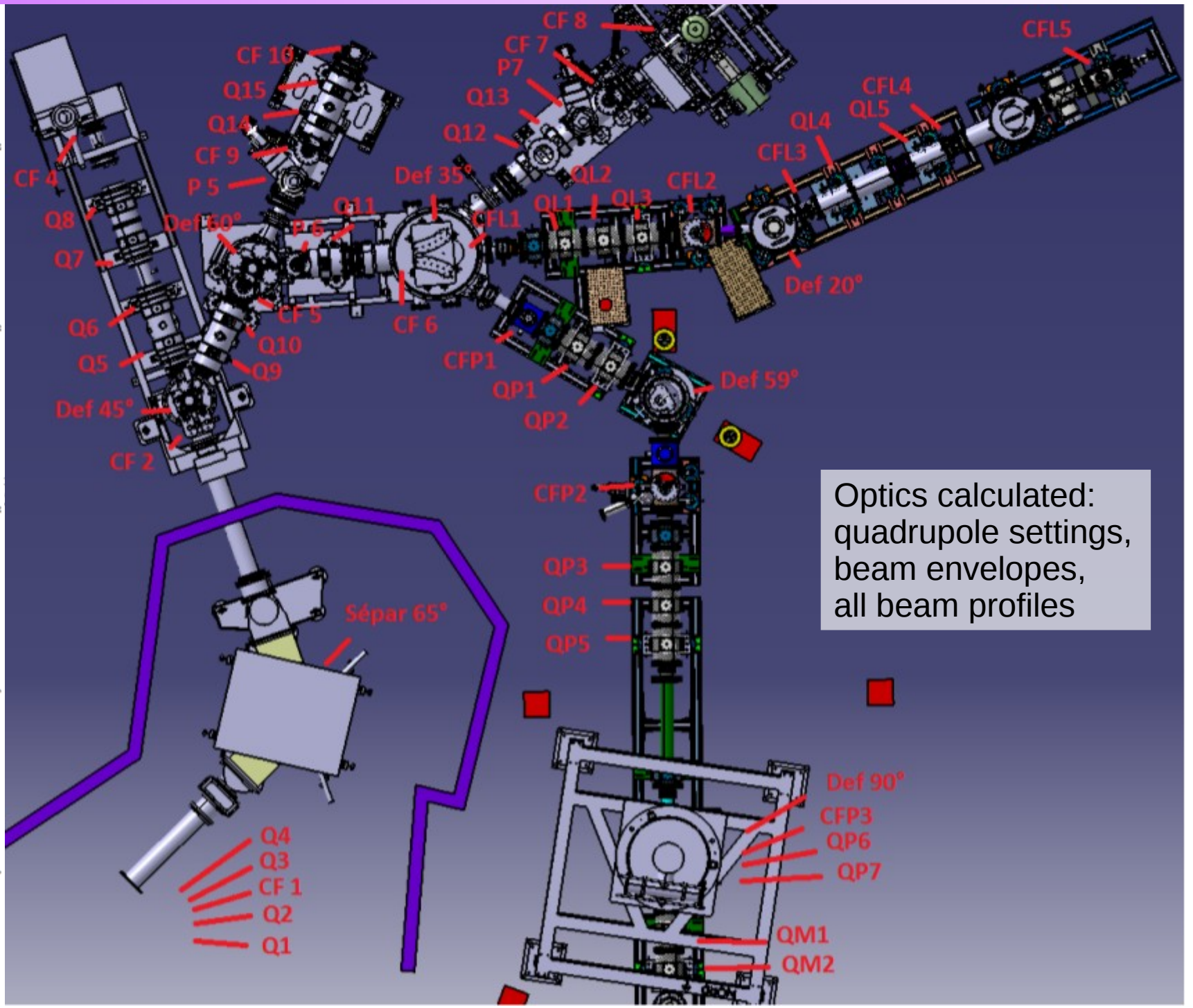


1. Polarex: electromagnetic moments
2. MLLtrap: mass measurements
3. MLLtrap: in-trap spectroscopy
4. Lino: moments for short half-lives
5. S3 at Spiral-2: superheavy nuclei

November 2016:
RFQ in front of MLLtrap
integrated drawing for all beam lines
delimitation of experiment vs infrastructure

Terra Incognita





Optics calculated:
quadrupole settings,
beam envelopes,
all beam profiles

A Hüe

1. Polarex: low-temperature nuclear orientation

77 K reached March 2017
10 mK this December 2017
awaiting mechanics for Ge detectors

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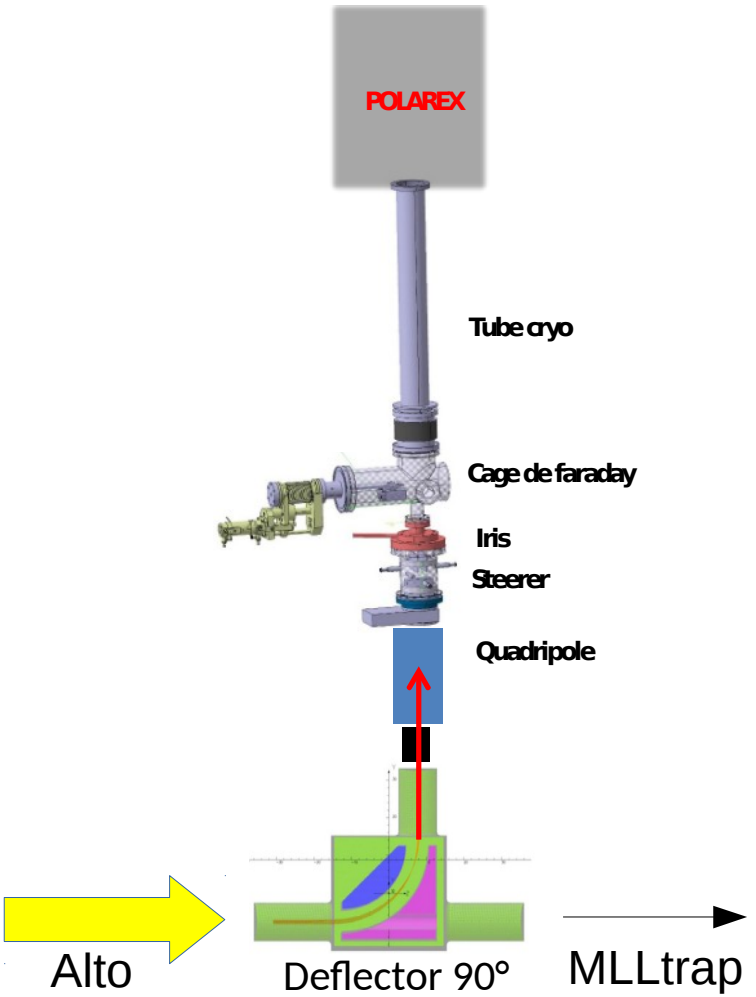
1. Polarex: low-temperature nuclear orientation



C Gaulard, F Leblanc & S Roccia
CSNSM design office,
H Ramarijaona

P2IO

adaptation for vacuum and mechanics	5 kE
support structure for detectors	20 kE
automatisation of vacuum and thermometry	30 kE
beam profiler	10 kE
HV, pumps, mechanics	30 kE
1/2 PhD R Thoer	75 kE
6 months CDD IR J Guillot	

ERM U-PSUD

90° deflector mechanics & HT	26 kE

AP IN2P3

90° deflector pumps	15 kE

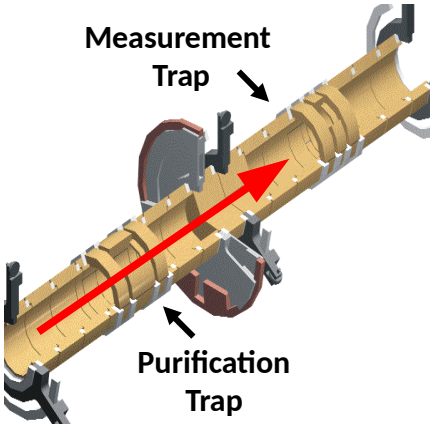
Sesame

horizontal beamline	246 kE

Planning

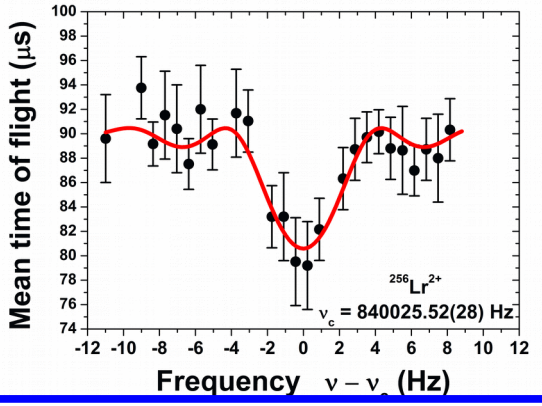
mK cryogenic tests	December 2017
design vertical beam line	January 2018
construct vertical beam line	1st semester
workshop LTNO	Spring 2018
20 kBq Pm:Fe source	June 2018
construct horizontal beam line	2nd semester 2018
commissioning with Pm:Fe	Autumn 2018
on-line	2019

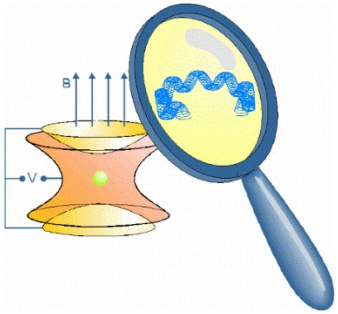
2. MLLtrap: mass measurements



Time-of-flight ion-cyclotron-resonance

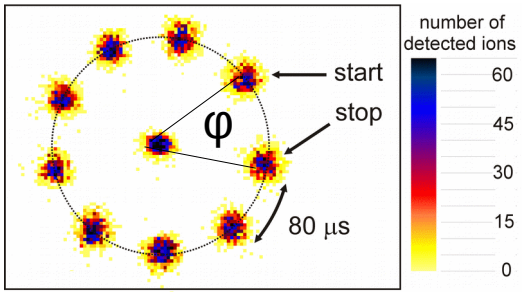
E Minaya Ramirez et al, Science 337 (2012)





Phase-imaging ion-cyclotron-resonance

Eliseev et al, PRL 110 (2013)

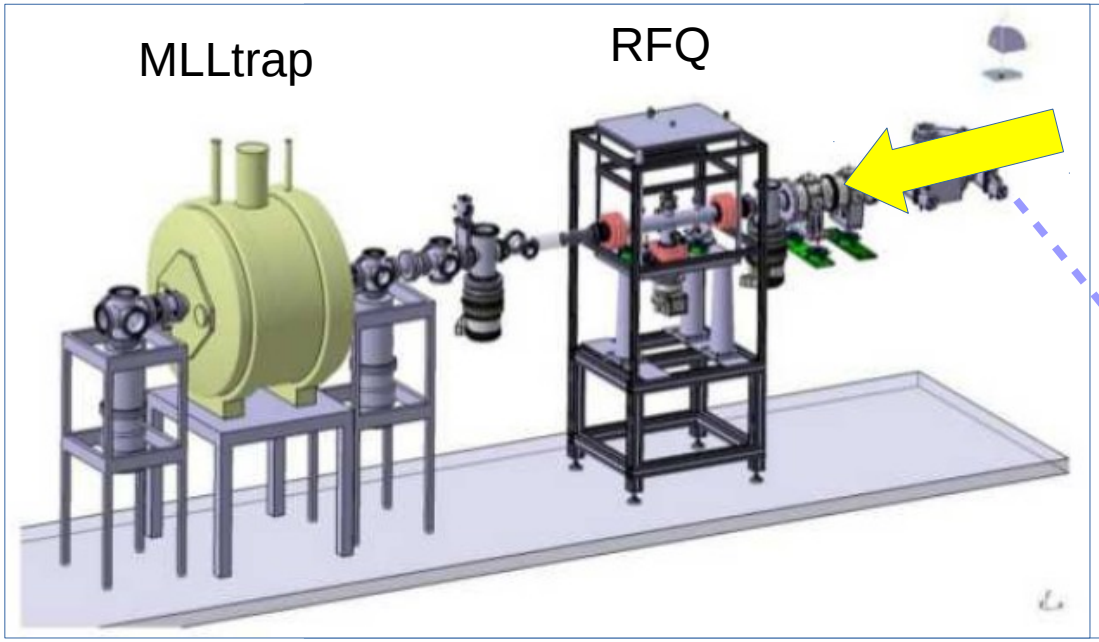


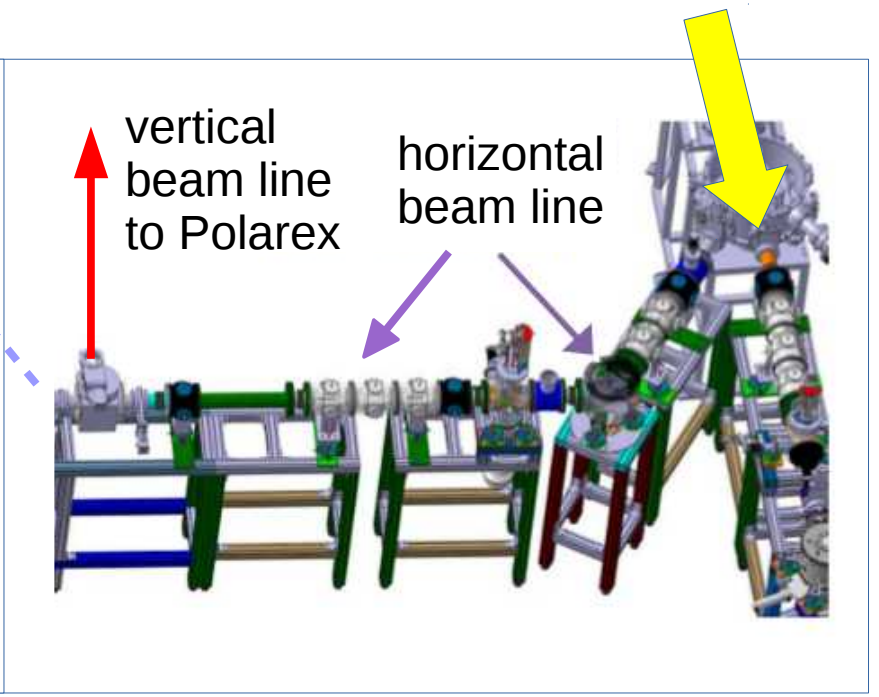
Phase imaging

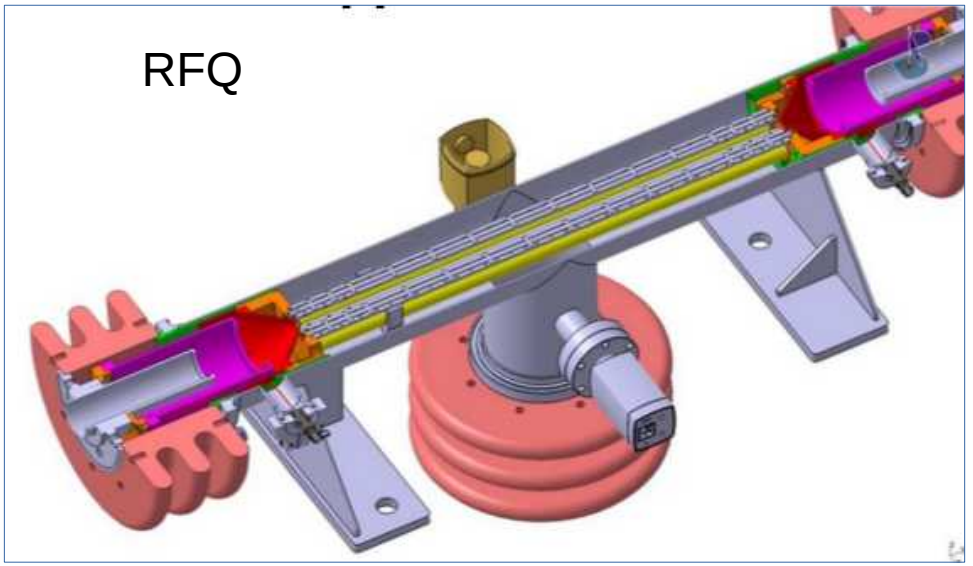
Tof

Chemistry: identification of molecules	10^{-5} - 10^{-6}
Nuclear physics: shells & pairing	10^{-6}
Astrophysics : r(p)-process, waiting points	10^{-7}
Nuclear structure: deformation, halos, IMME	10^{-7} - 10^{-8}
Weak interaction studies: CVC & CKM	10^{-8}
Atomic physics: binding energies, QED	10^{-9} - 10^{-11}
Metrology: fundamental constants, CPT	$\leq 10^{-10}$

2. MLLtrap: mass measurements

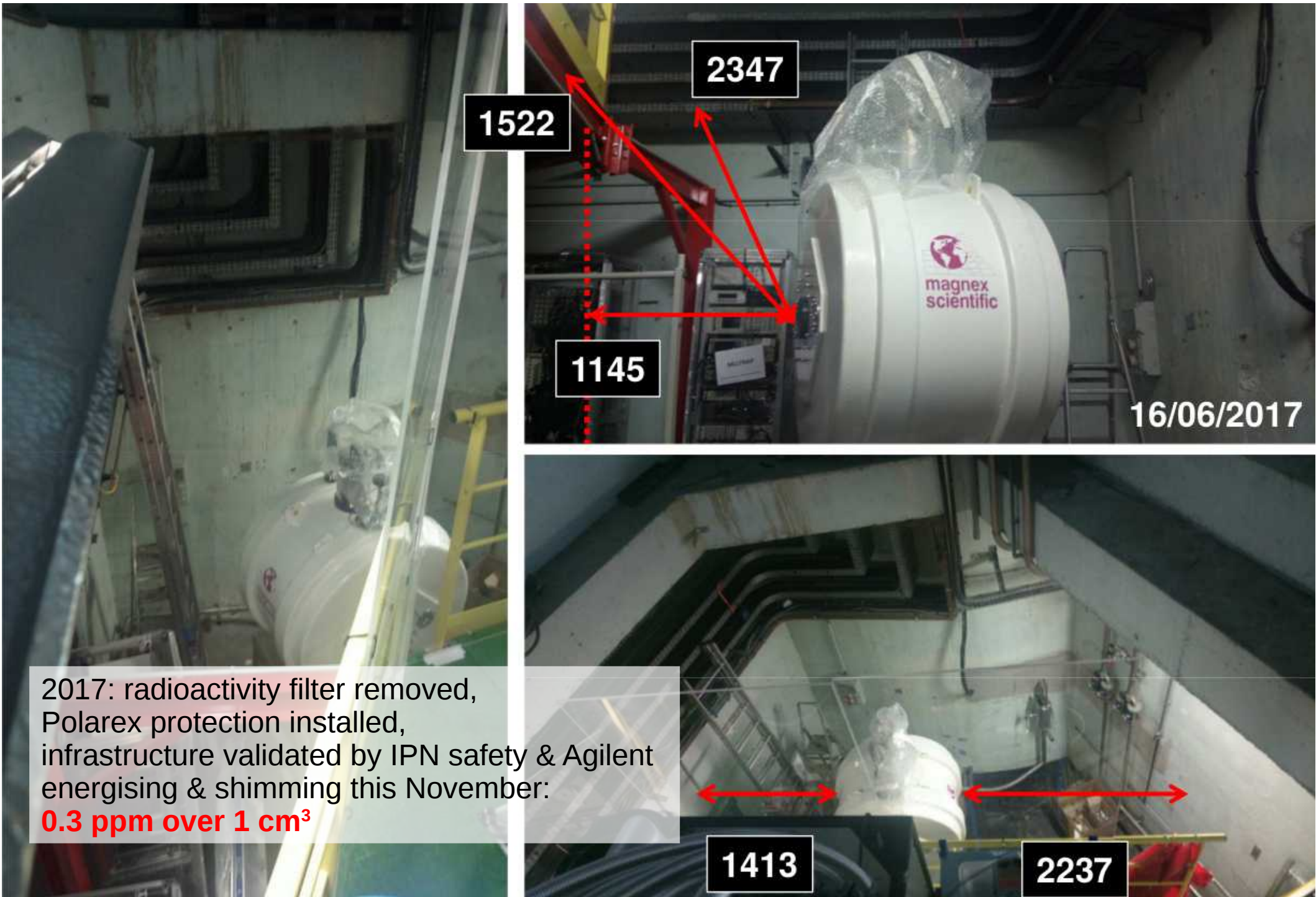






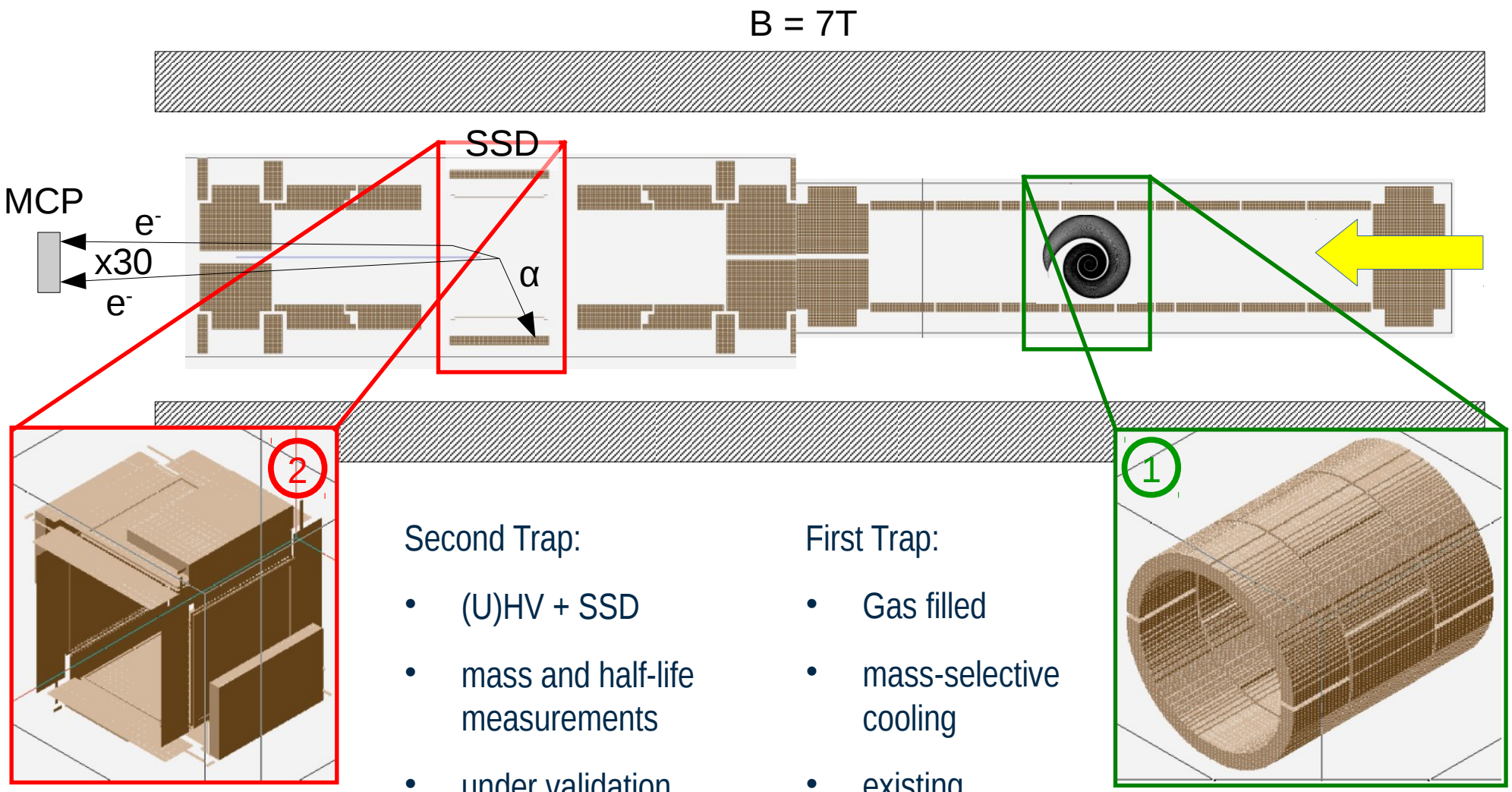
RFQ design nearly complete
50 cm leeway for ejection or injection
all equipment identified through Sesame
"Reaching Terra Incognita of Exotic Nuclei"

E Minaya Ramirez, M MacCormick, L Perrot
IPN design office, P Blache



2017: radioactivity filter removed,
Polarex protection installed,
infrastructure validated by IPN safety & Agilent
energising & shimming this November:
0.3 ppm over 1 cm^3

3. In-trap spectroscopy: nuclear-level half-lives



Second Trap:

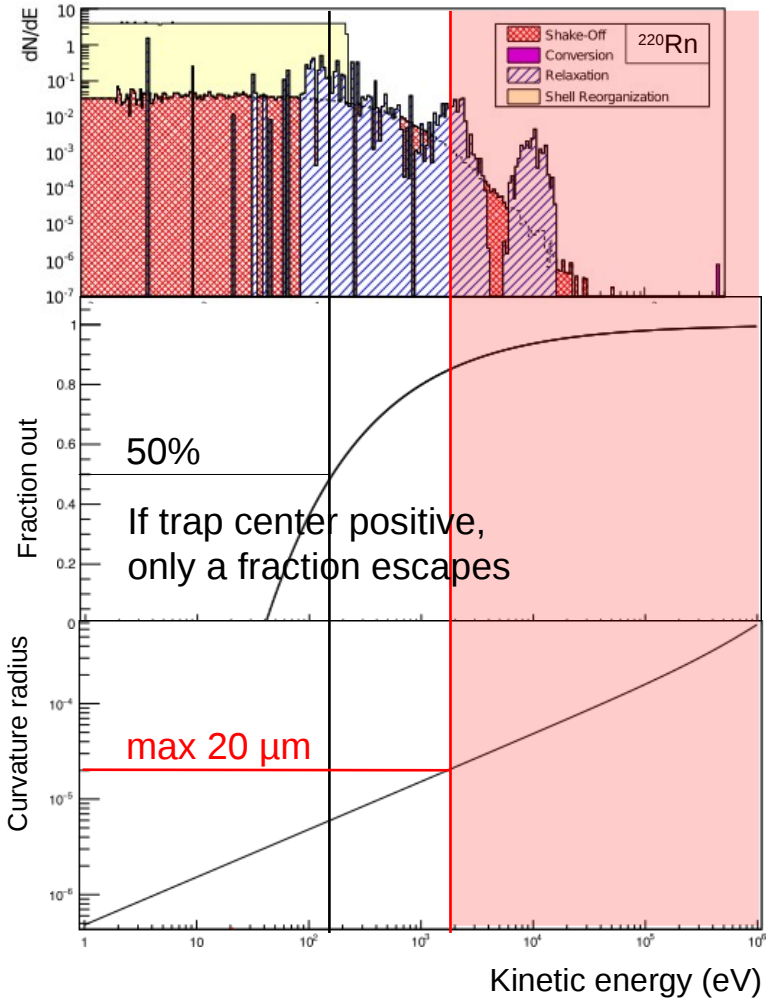
- (U)HV + SSD
- mass and half-life measurements
- under validation

First Trap:

- Gas filled
- mass-selective cooling
- existing

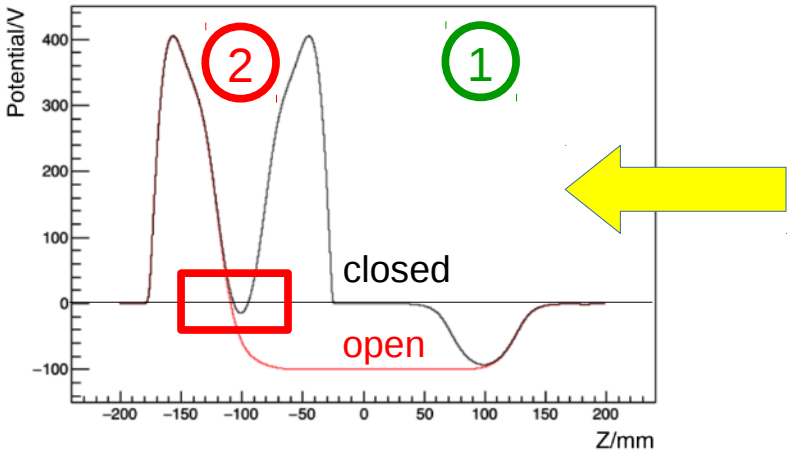
half-life measurements of nuclear levels:
simulate cooling & validate detector in magnetic field
A Lopez-Martens & P Chauveau

3. In-trap spectroscopy: nuclear-level half-lives

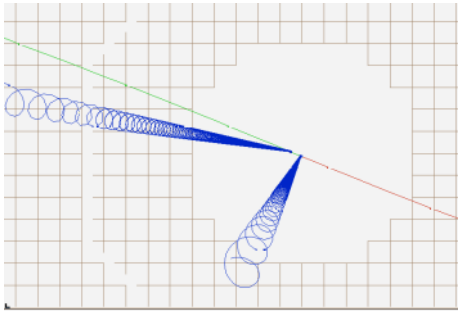


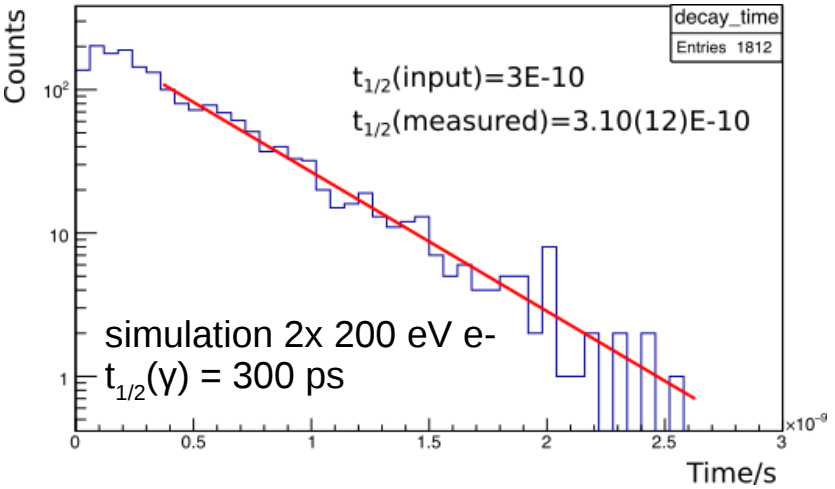
N Wandkowsky et al, New J Phys 15 (2013)

SSD 30x30 mm^2 with 30 strips of 1 mm thickness ~0.5 mm, 20 keV resolution
detect α particle rather than conversion e-
no PSA therefore limited synergy with task 4

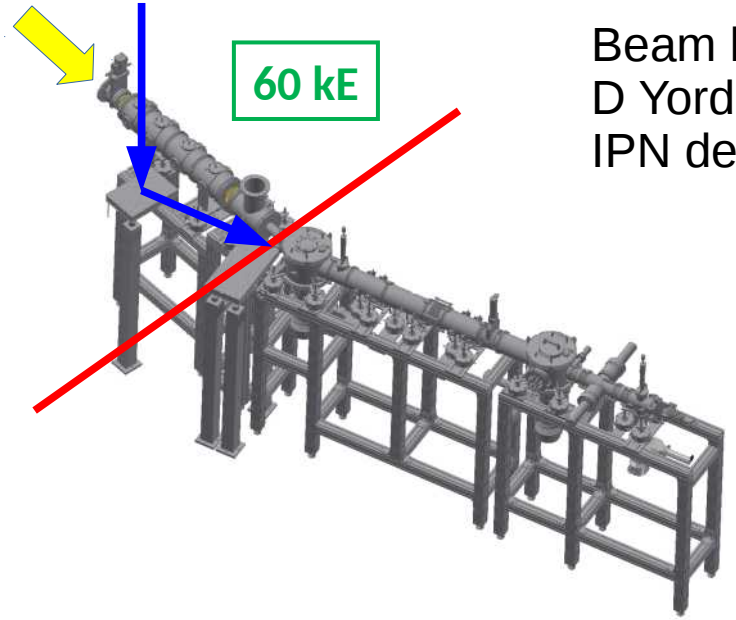


add negative electrodes inside trap
so low-energy electrons may escape

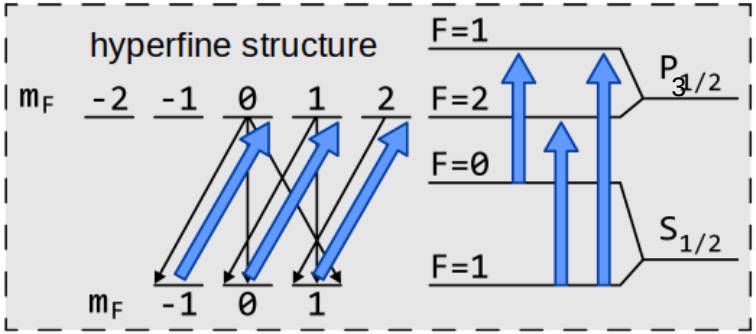




4. Lino: laser-induced nuclear orientation



Beam line design completed
D Yordanov
IPN design office, JM Dufour



fluorescence detection

post acceleration & neutralization

beam diagnostics and handling

laser and ion beam coupling

Tender #1:
20˚ bender
X-Y deflectors
FC

30 kE

Tender #2:
Einzel lens
CEC
Opt. detection
FC
10 kV insulators
Brewster windows

Acquired:
NEC EQT 64-15
2 x HiPace 700, 2 x HiPace 300
2 x ACP 28, 1 x ACP 15
2 x VAT 160, 2 x VAT 100

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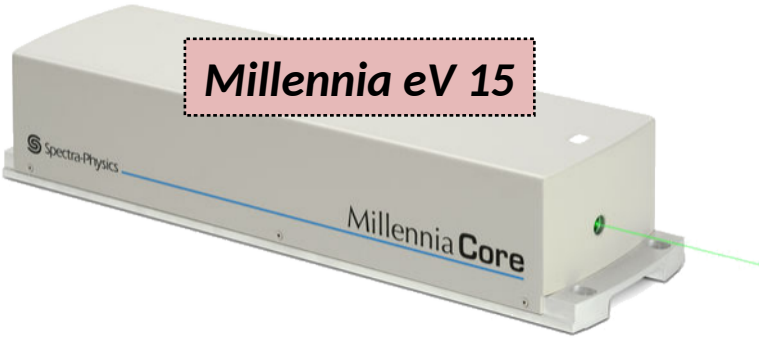
HV tested during Alto experiment Oct 17
Data acquisition being prepared

Acquired:
NIM electronics
TREK 10/10B-HS-H-CE
Ohm labs KV-10R
Keysight AV-34470A
Detectors

Needed:
Heating power supply
Floating transformer
Deflector
Divider
Optics

20 kE

Renew laser system



110 kE (?)

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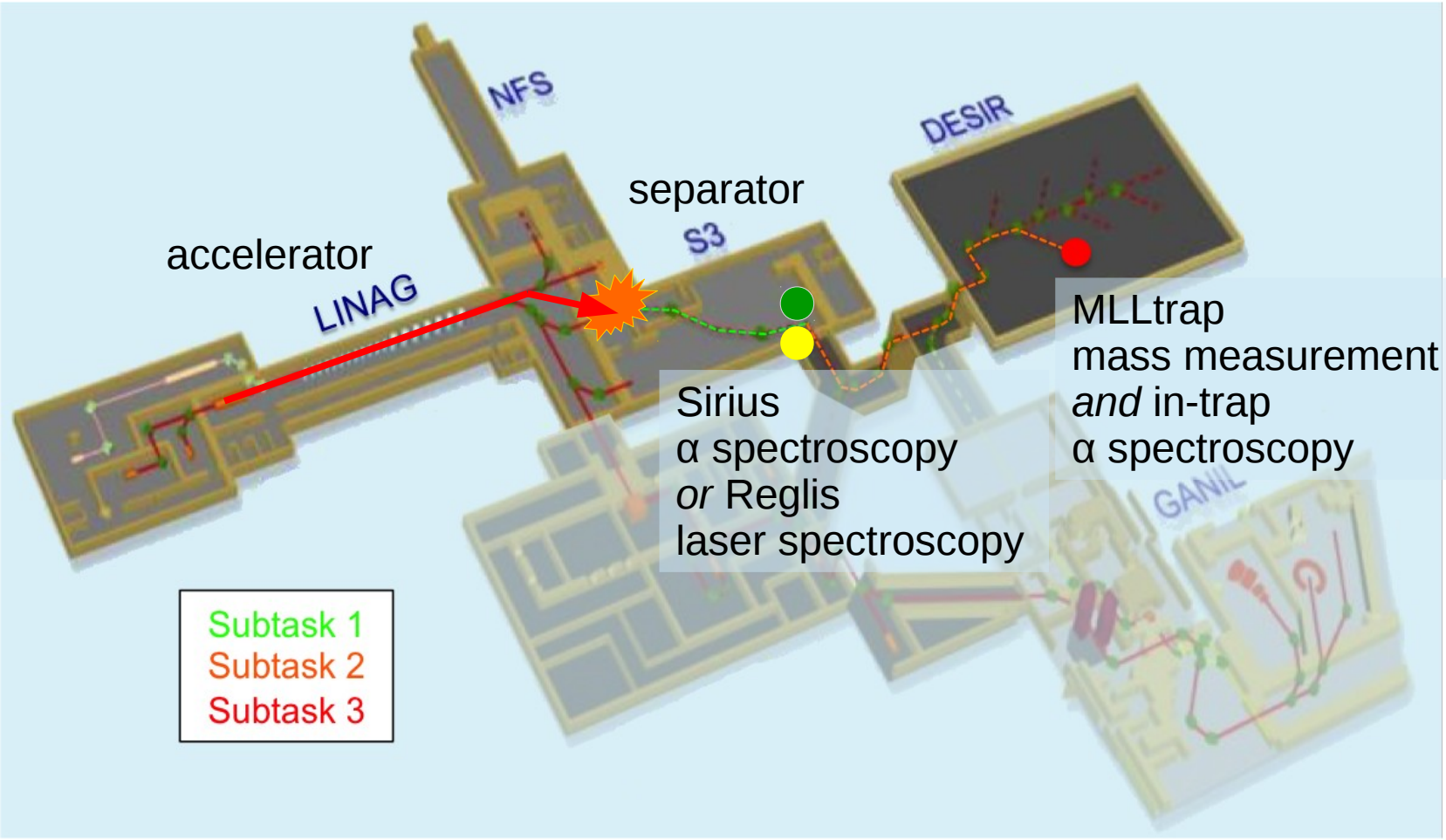
5. Super Spectrometer Separator at Spiral-2



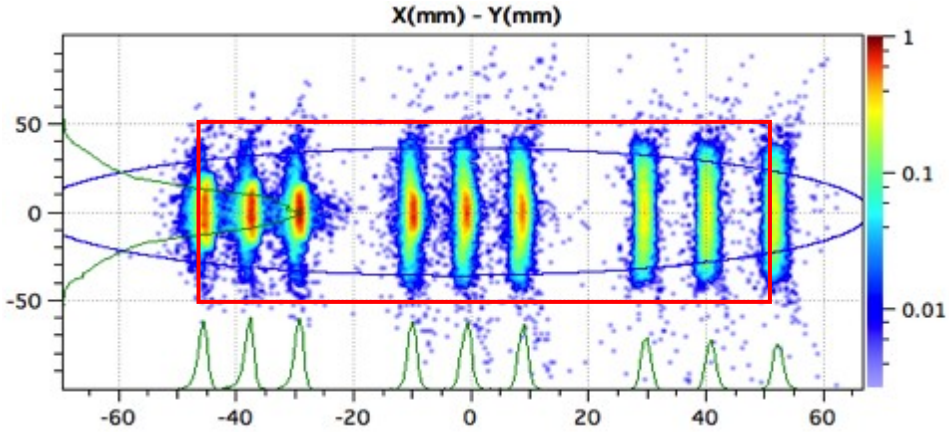
α & e- spectroscopy of K-isomers in superheavy elements
pulse-shape analysis (PSA) for Sirius detector, B Sulignano & J Kallunkathariyil

mass measurements and in-trap spectroscopy with MLLtrap
S3 optics for Reglis detector, A Drouart & T Guigoux

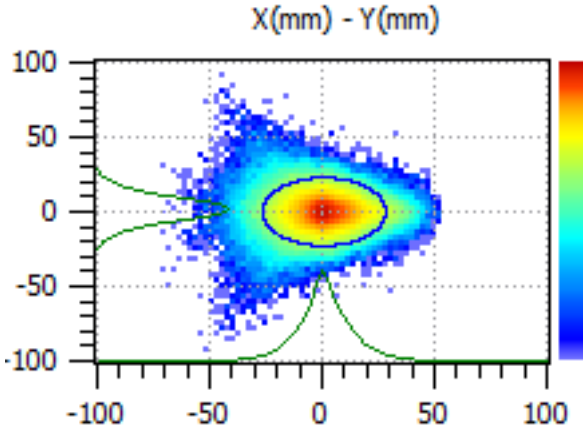
simulation of two optical modes for S^3
reference beam A = 100, Q = 24^+, σ_p = 3.7%, σ_P = 18 mrad

Sirius:
high-resolution mode for maximum resolution

M/ΔM = 500 (FWHM)
3 charge states
transmission
in 10x10 cm^2 = 37%



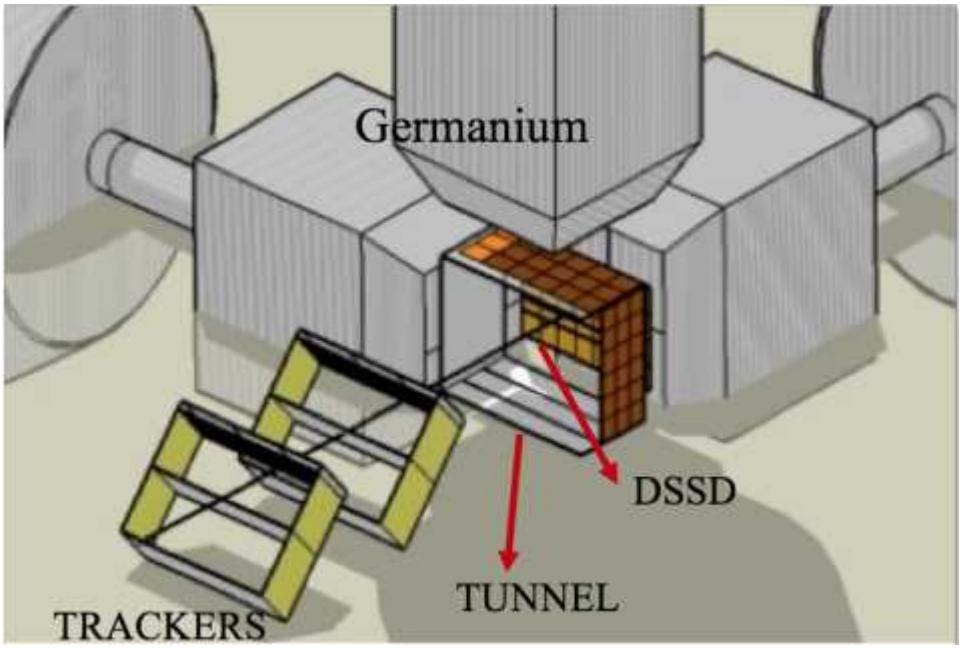
Reglis:
convergent mode for maximum transmission



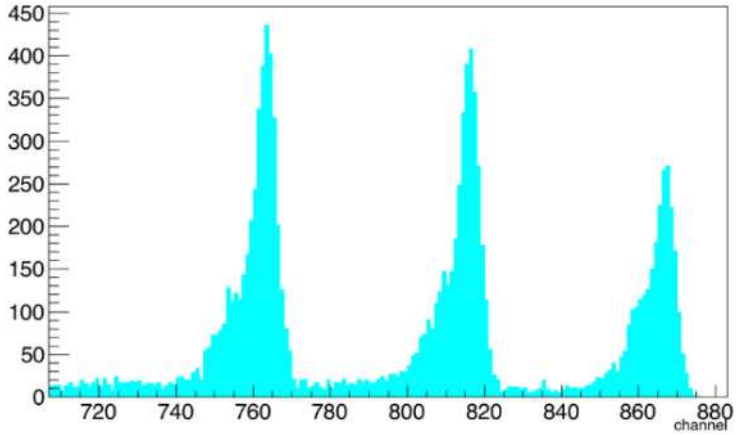
no mass resolution
6 charge states
transmission Ø 5cm = 60%

Sirius detector for superheavy elements

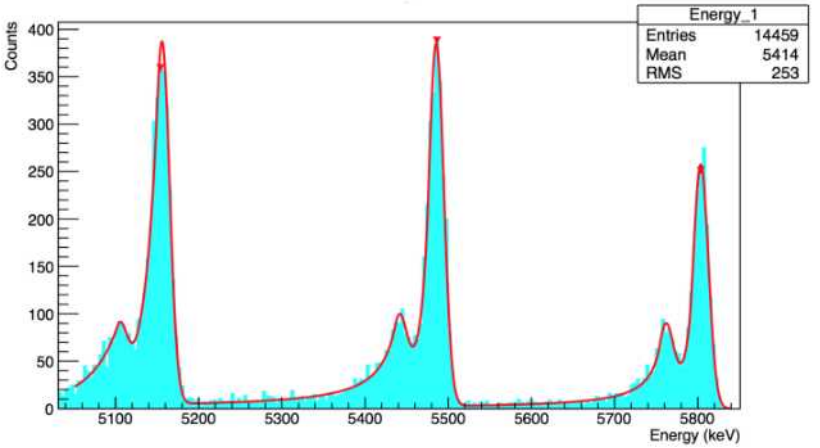
DSSD 128 x 128 strips



raw α spectrum



filtered
20 keV FWHM



developed PSA algorithm
tested DSSD with α source

<u>new synergy</u>: α identification for Reglis

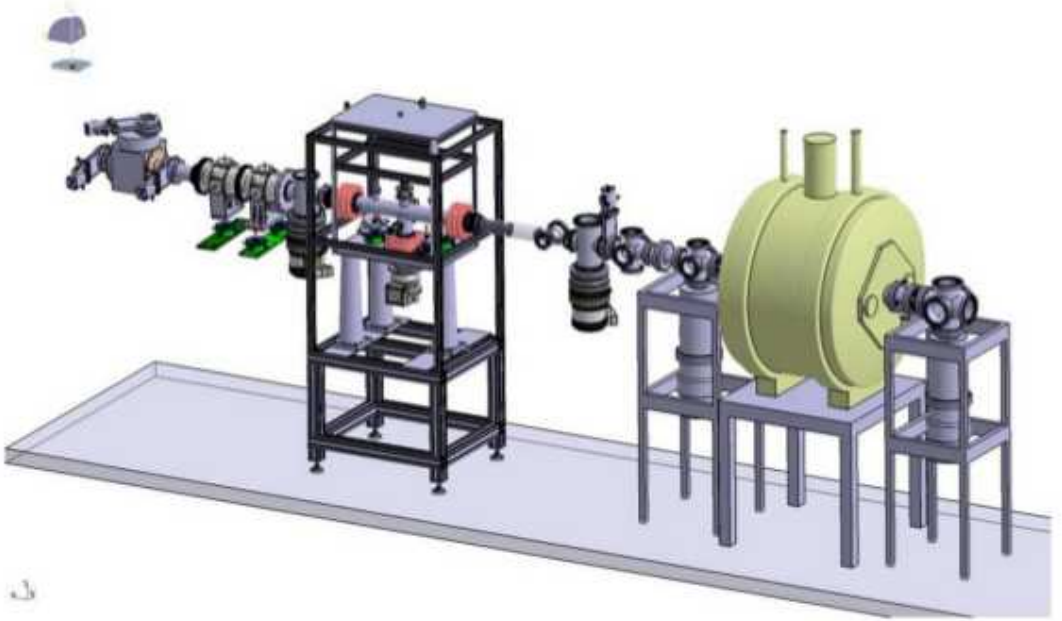
Status of Alto

Experiment October 2017
- accelerator, ion source, lasers: ok
- beam extraction high voltage & Faraday cups: repaired
- detection & tape station: Terra Incognita to be involved?

Improve reliability of Alto
- independent optical paths for laser: done
- annex oven & mass scan for ion source & separator: done
- beam transport: to be investigated further

Conclusions

- Sesame "Reaching Terra Incognita of Exotic Nuclei" 580 kE
- design mostly complete but RFQ & beam line await arrival of funding
- laser ionisation for silver, the first physics case for MLLtrap



2. MLLtrap: mass measurements

Funding

infrastructure IPN-LAL	70 kE
detection P2IO	30 kE
Sesame horizontal beam line	246 kE
Sesame RFQ	306 kE
running cost (helium...)	10 kE /year 2018+

Planning

RFQ design	December 2017
mount traps & vacuum testing	1st semester 2018
design horizontal beamline	
RFQ construction	
construct horizontal beamline	2nd semester 2018
commissioning	2nd semester 2018
online	June 2019

3. In-trap spectroscopy: nuclear-level half-lives

Funding

IN2P3 postdoc P Chauveau	100 kE
detection	60 kE

Planning

Simion simulations for mechanical design	December 2017
Geant4 simulations of electron detection	1st semester 2018
construct detectors	2nd semester 2018
install detectors in MLLtrap	2019

4. Lino: laser-induced nuclear orientation

Funding

first beam line	60 kE
second beam line	30 kE
power supplies	10 kE
vacuum flanges, optics	5 kE
HT, daq	5 kE
lasers	85 kE (pump laser on hold)

Planning

call for tender for beam line & laser	December 2017
beam line assembly	first semester 2018
commissioning	second semester 2018
develop acquisition software	December 2018
online	2019

5. Super Spectrometer Separator at Spiral-2

Funding

P2IO postdoc J Kallunkathariyil	50 kE
P2IO postdoc T Guigoux	100 kE
1/2 PhD	50 kE
travel to Ganil	10 kE

Planning

user friendly analysis software for S3 optics	2018
online and offline programs for Sirius data treatment	2018
test Sirius detector at S3	2019
S3 commissioning	2019-20

Funding P2IO 664 kE

Polarex	95 + *75 kE*
MLLtrap	30 kE
in-trap	60 kE
Lino	194 kE
S3	*210 kE*

IPN-LAL & IN2P3 185 kE

Polarex	15 kE
MLLtrap	70 kE
in-trap	*100 kE*

ERM 26 kE

Polarex	26 kE

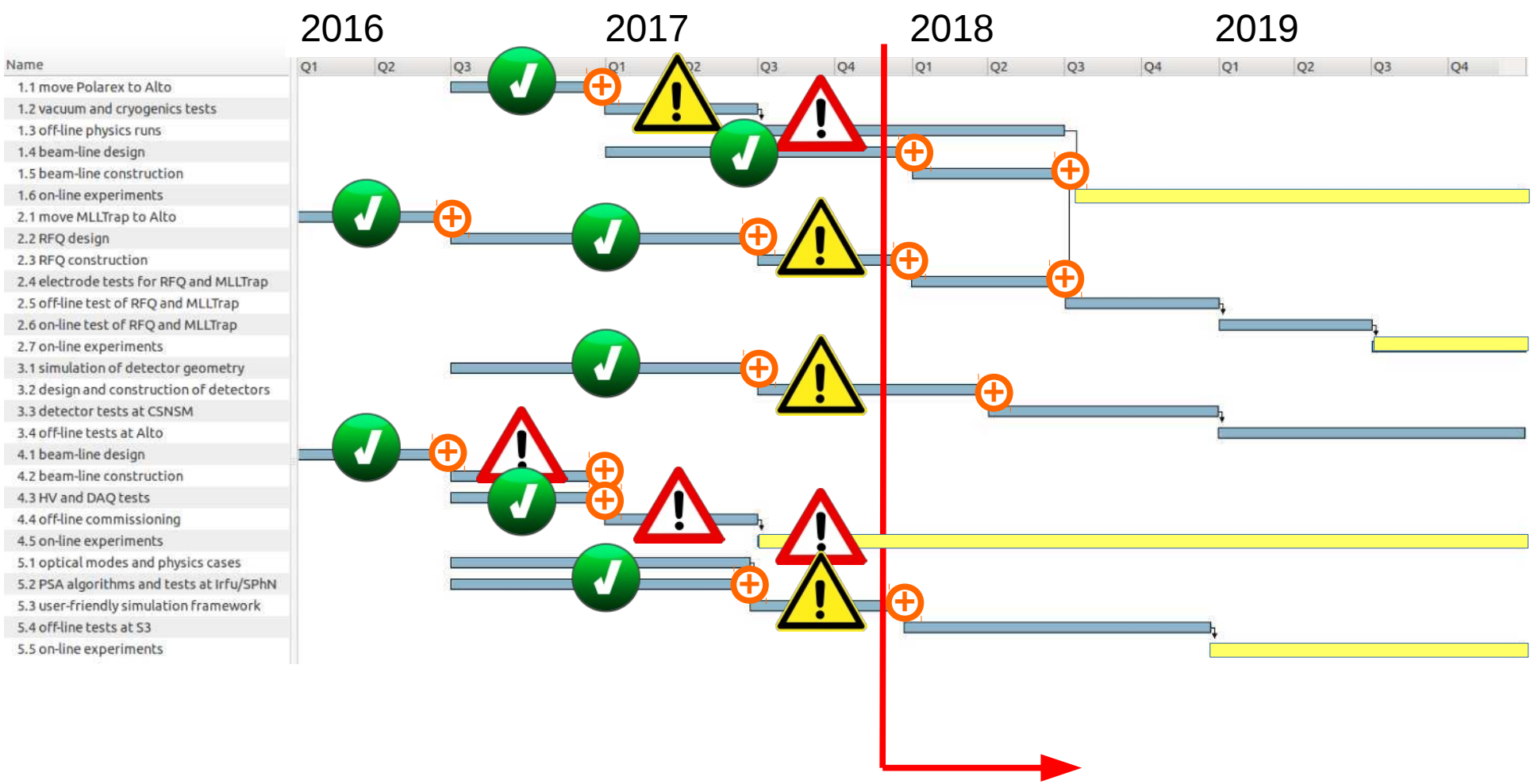
Sesame "Retien" 580 kE

"Reaching Terra Incognita of Exotic Nuclei"

MLLtrap RFQ	306 kE
horizontal beam line	246 kE
Caylar	28 kE

personnel in italics

Planning



1.2 will be done in December
2.3 wait for Sesame funds
3.2 & 5.3 delayed arrival postdoc