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$\beta-\nu$ correlation measurements with LPCTrap

E. Liénard, G. Ban, M. Breitenfeldt, C. Couratin, P. Delahaye, D. Durand, X. Fléchard, F. Mauger, A. Méry, O. Naviliat-Cuncic, G. Quéméner, T. Porobic, D. Rodríguez, N. Severijns, J. C. Thomas, S. Van Gorp

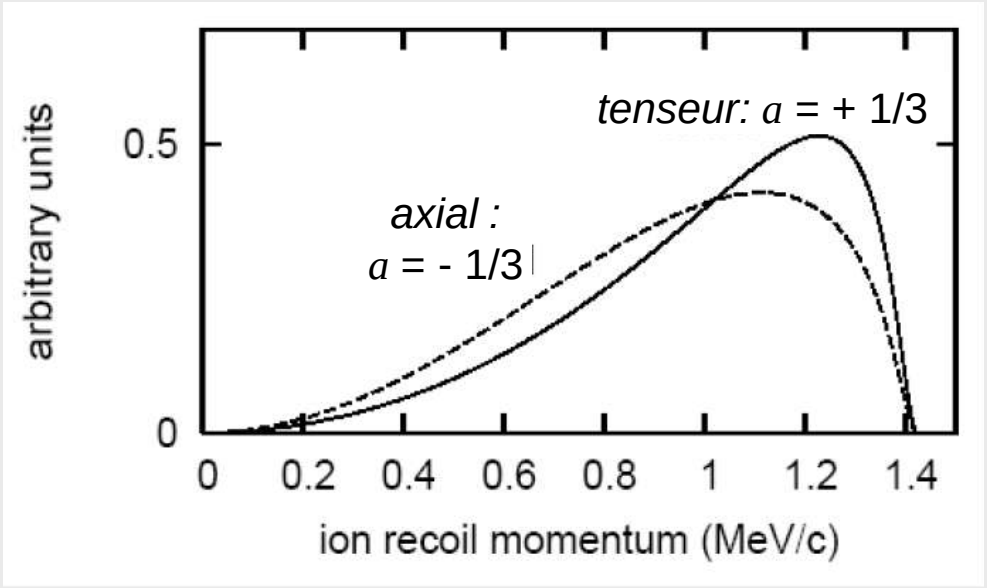
LPC-Caen, GANIL, CIMAP, KUL, MSU, Univ. de Granada

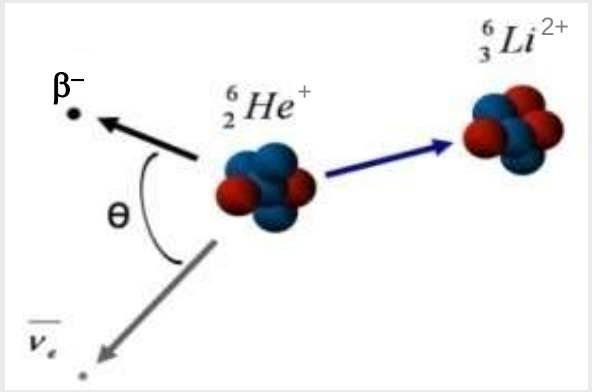
Measurement of a in unpolarized nuclei *

$$W(E,\theta) = W(E)\,[1 + a\,\frac{v_e}{c}\cos(\theta) + b\,\frac{m}{E}\,]$$

Any observable linked to (θ) will be sensitive to a

Recoil ion momentum





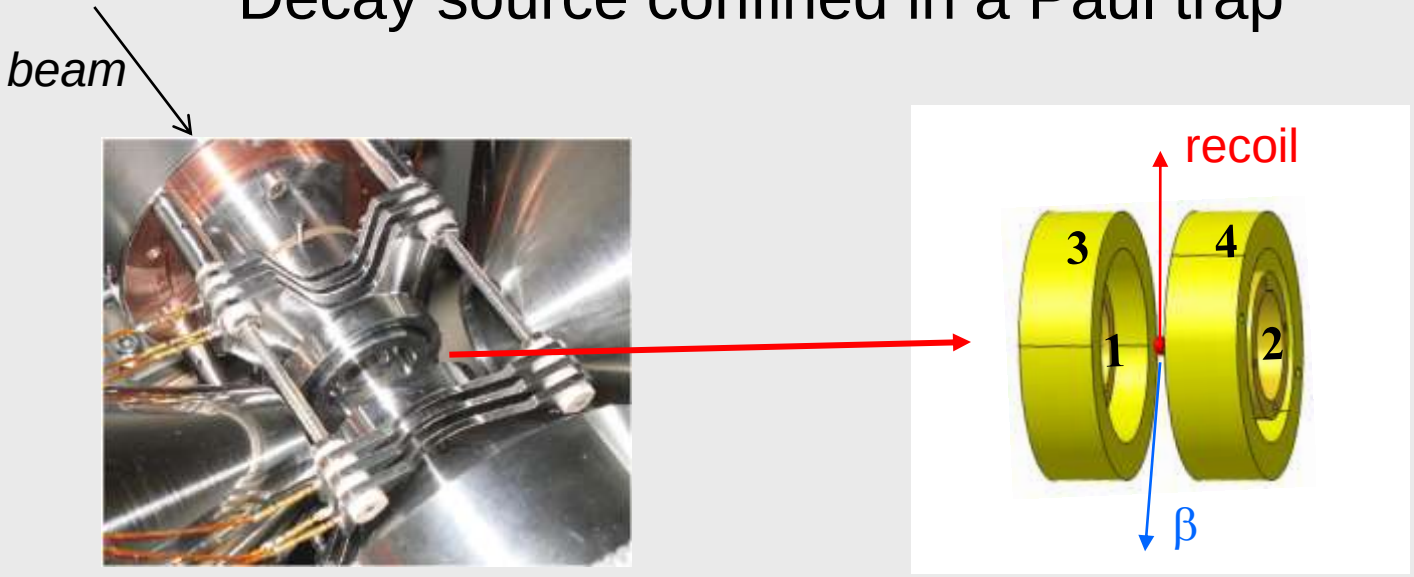
Very low kinetic energy (< 1 keV)

→ Trapping technique for direct measurement

** Motivation : see talk of O. Naviliat-Cuncic*

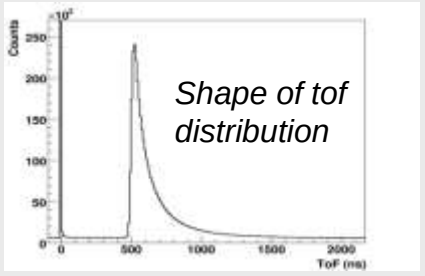
Measurement of *a* in unpolarized nuclei

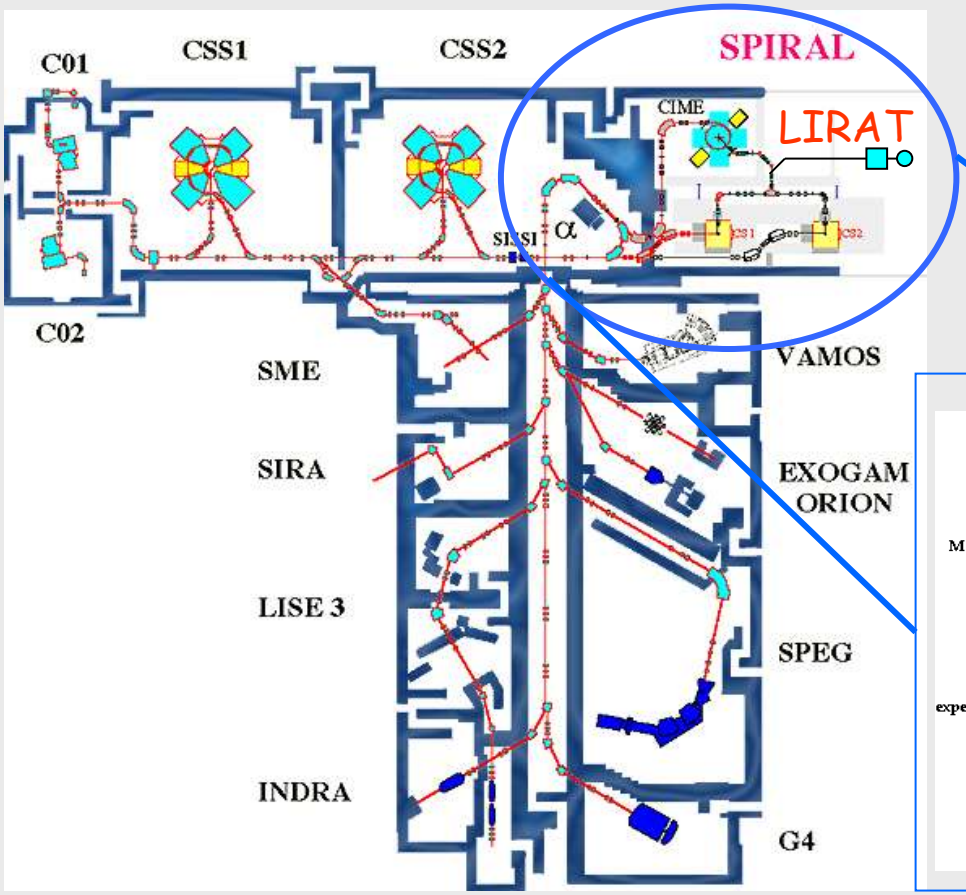
Decay source confined in a Paul trap



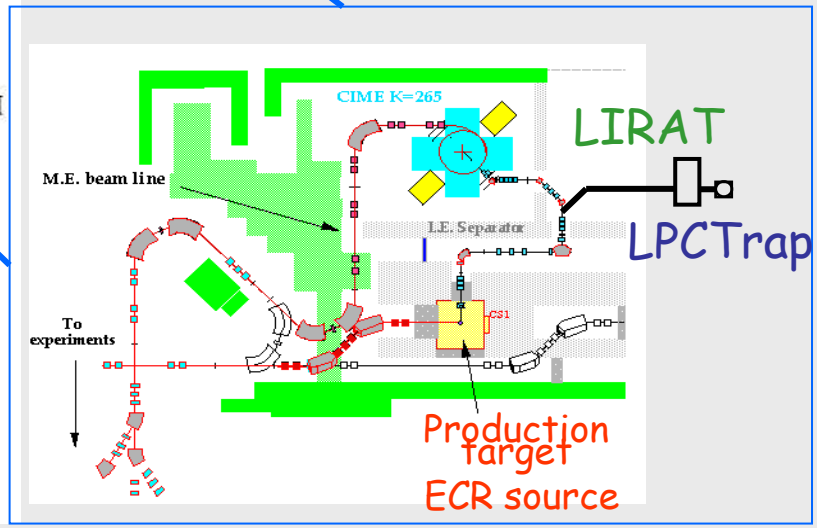
- ions « at rest » in vacuum
- ions well localized
- open geometry : high detection solid angle

- β - recoil ion coincidences measurement
- *a* deduced from recoil time-of-flight distribution





Beams characteristics :
- 10-30 keV, 80 π mm mrad
- rate : 10^7 - 10^8 ions/s

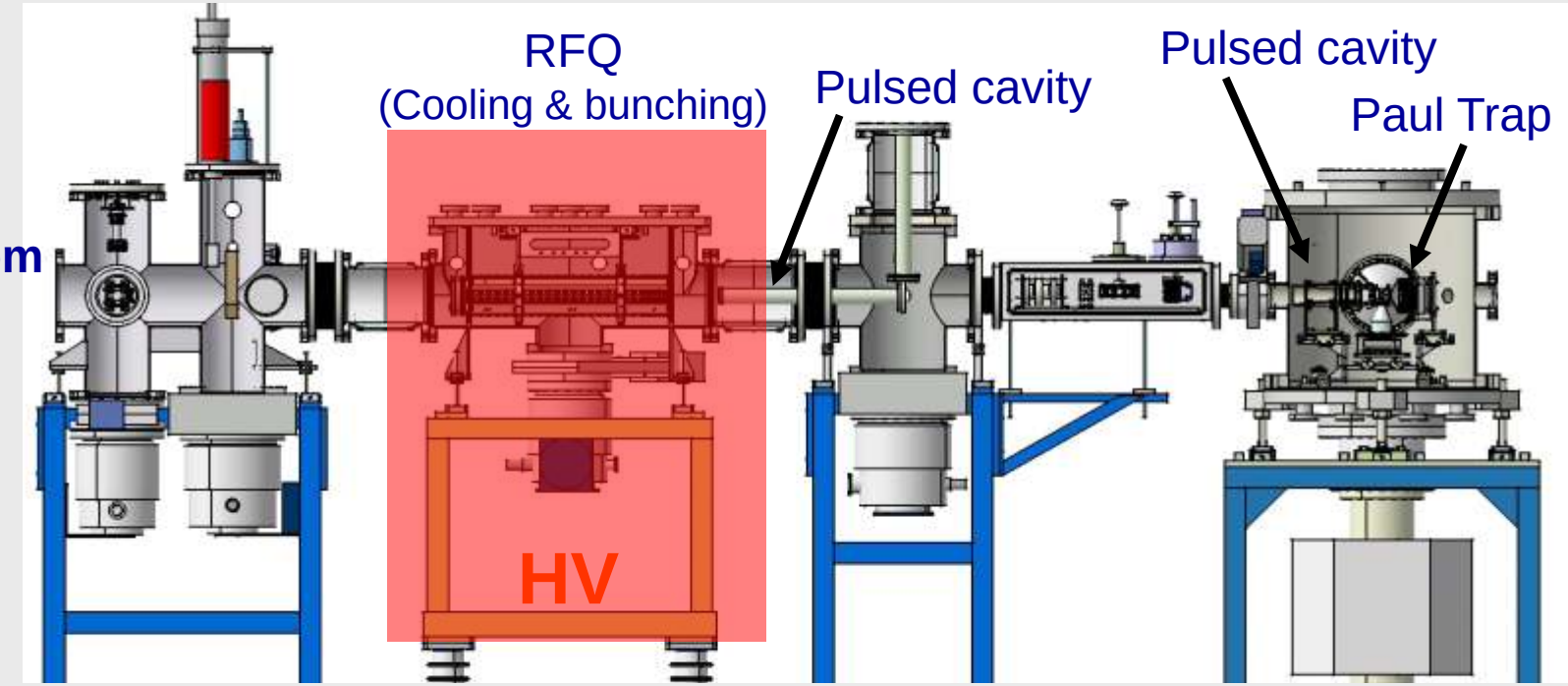


SPIRAL beam :
10-30 keV
ΔE ~ 20eV

?

Paul trap :
Effective potential :
2-3 V

Beam preparation line for trapping



KE_{ion} : 10 keV | 100 eV - <1 eV | 1 keV | 100 eV 0 eV

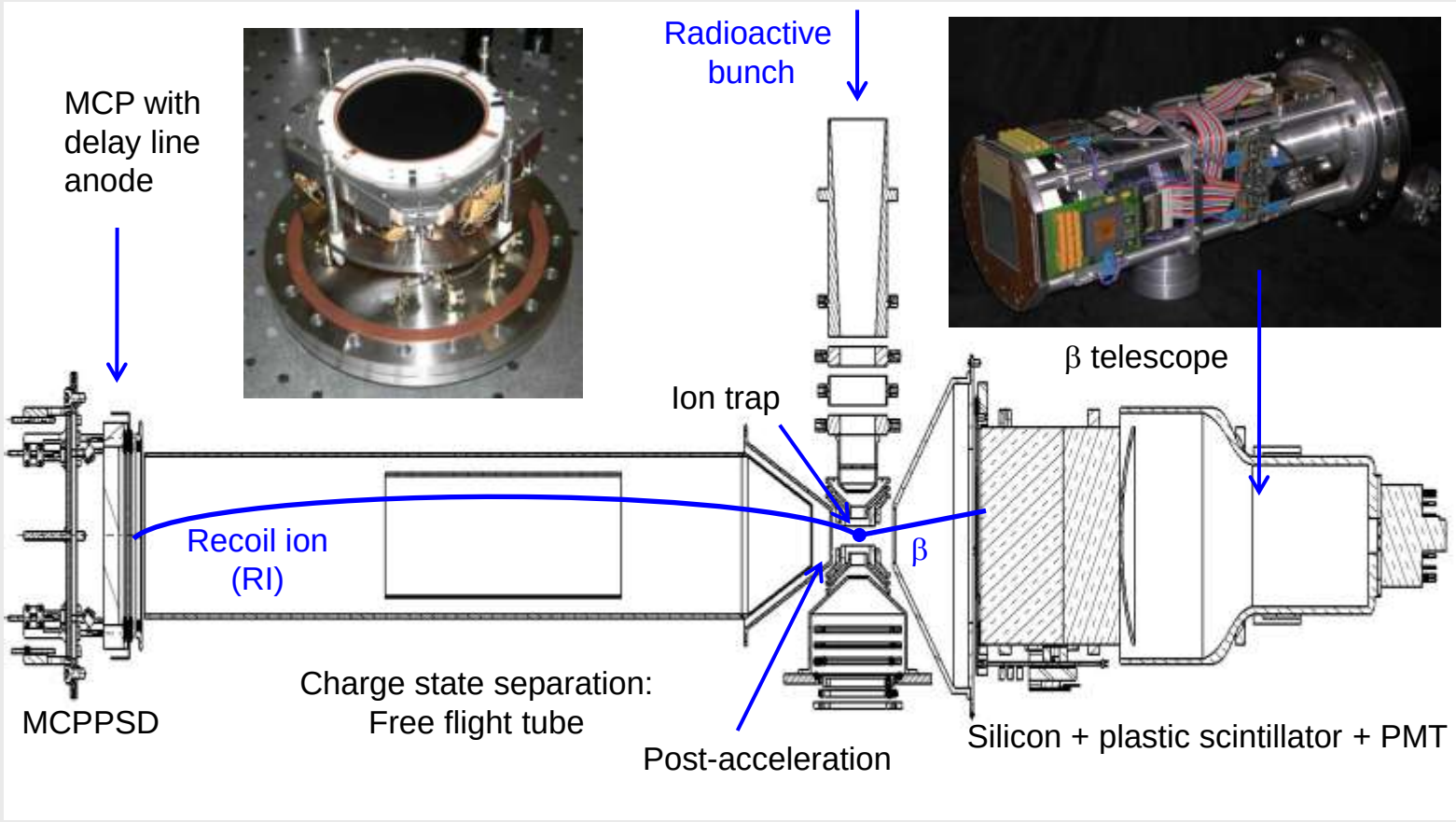
ΔKE: ~20 eV | ~1 eV | ~0.1 eV

10^8 pps

- Buffer-gas : H_2 / He
- accumulation : 200ms (cycle)

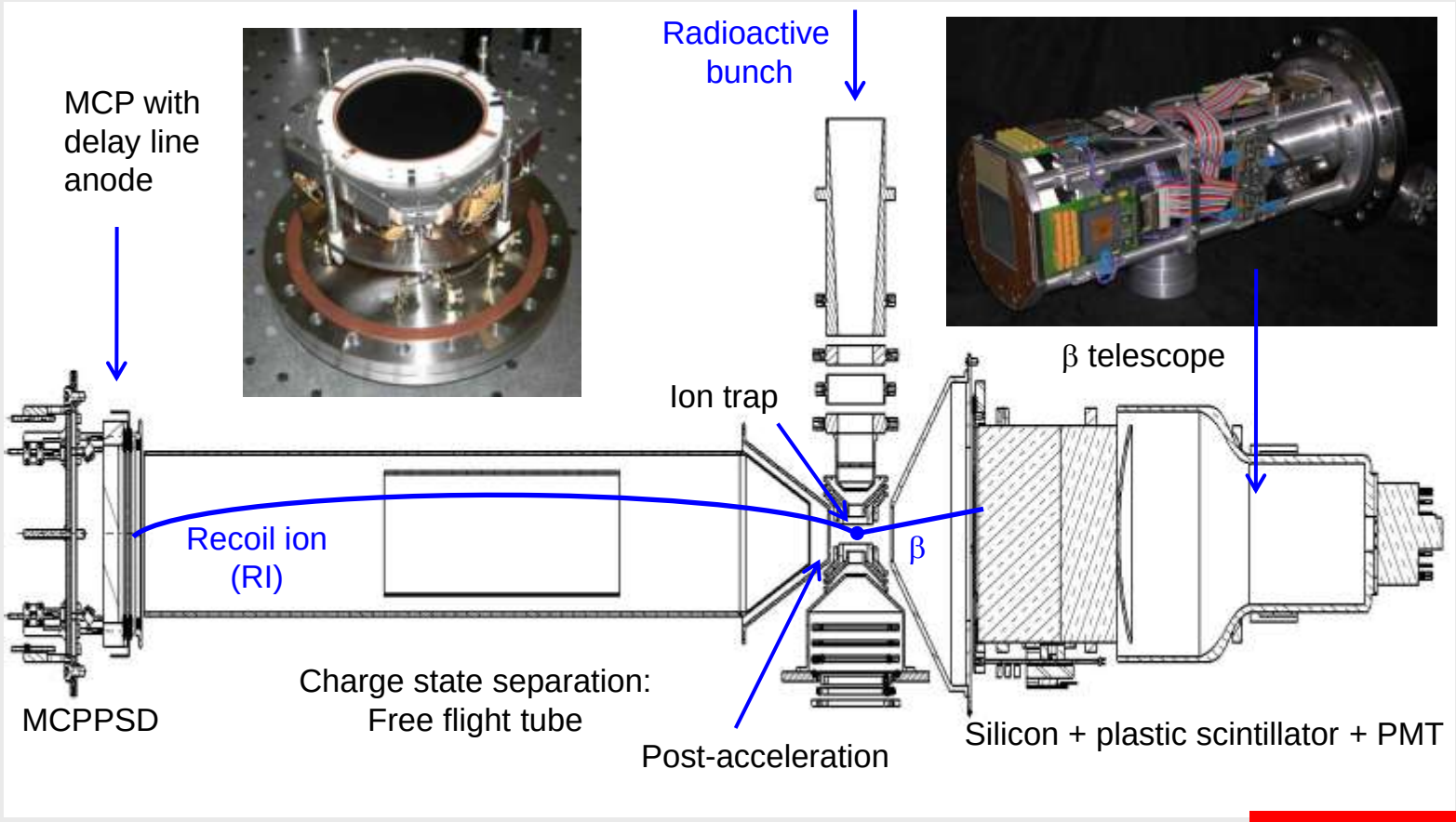
~10^4 trapped ions /cycle

Detection setup



- β-recoil detection → *particles positions, β energy & recoil tof*
- β detection → *timestamp in cycle & RF configuration*
- RI detection device → unique setup able to measure the different charge state distributions from ion decay (shake-off effect)

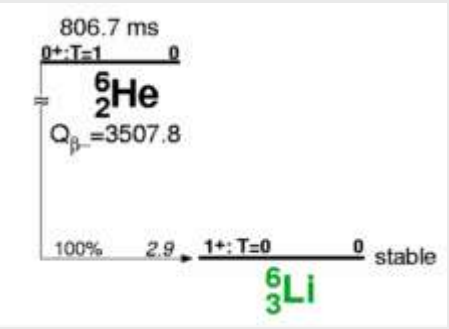
Detection setup



- β-recoil detection → *particles positions, β energy & recoil tof*
- β detection → *timestamp in cycle & RF configuration*

Control BG
Clean data
Check results

- RI detection device → unique setup able to measure the different charge state distributions from ion decay (shake-off effect)



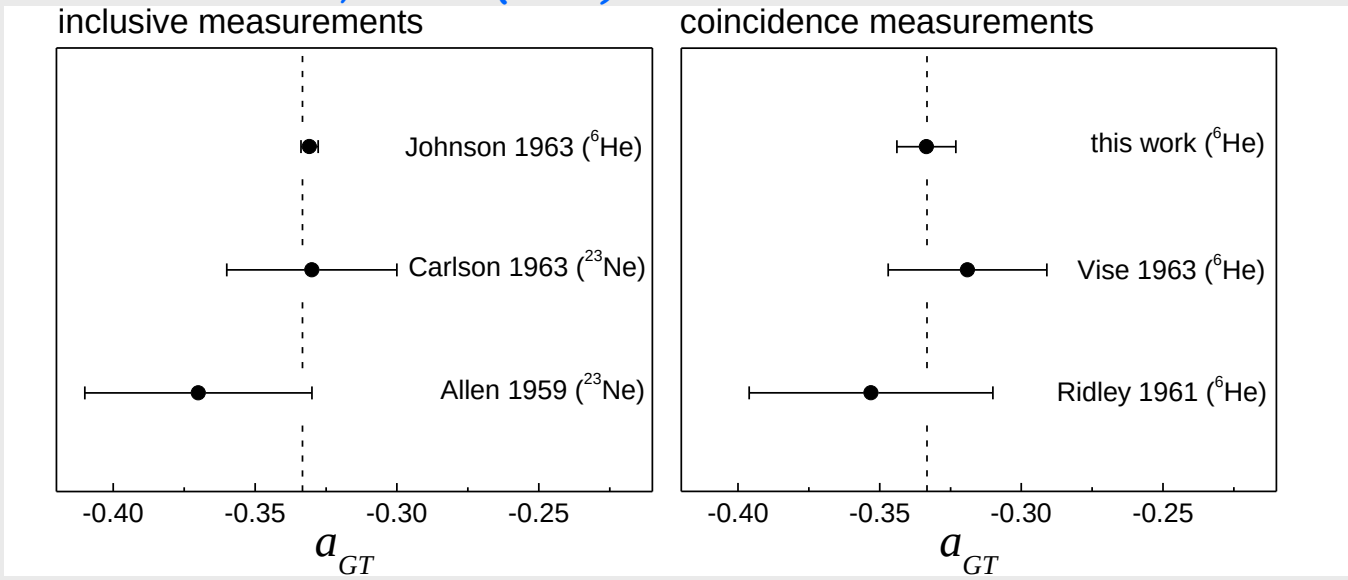
^{6}He : to constrain T current contribution

- First published value : a_{GT} = -0.3335 (73)(75)

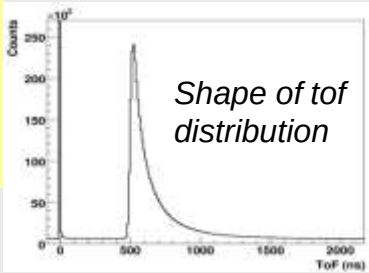
$5x10^4$ events (July 2006)

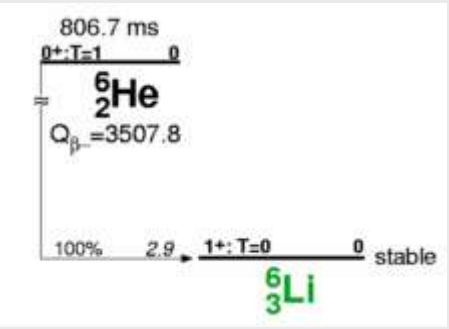
dominated by cloud T° (68)

Fléchard et al., JPG38(2011)



- Best value for GT & coincidence measurements
- High confidence level (check list of measured parameters)
- Cloud T° : fit with a @ high statistics (Ph. Velten, thesis 2011)





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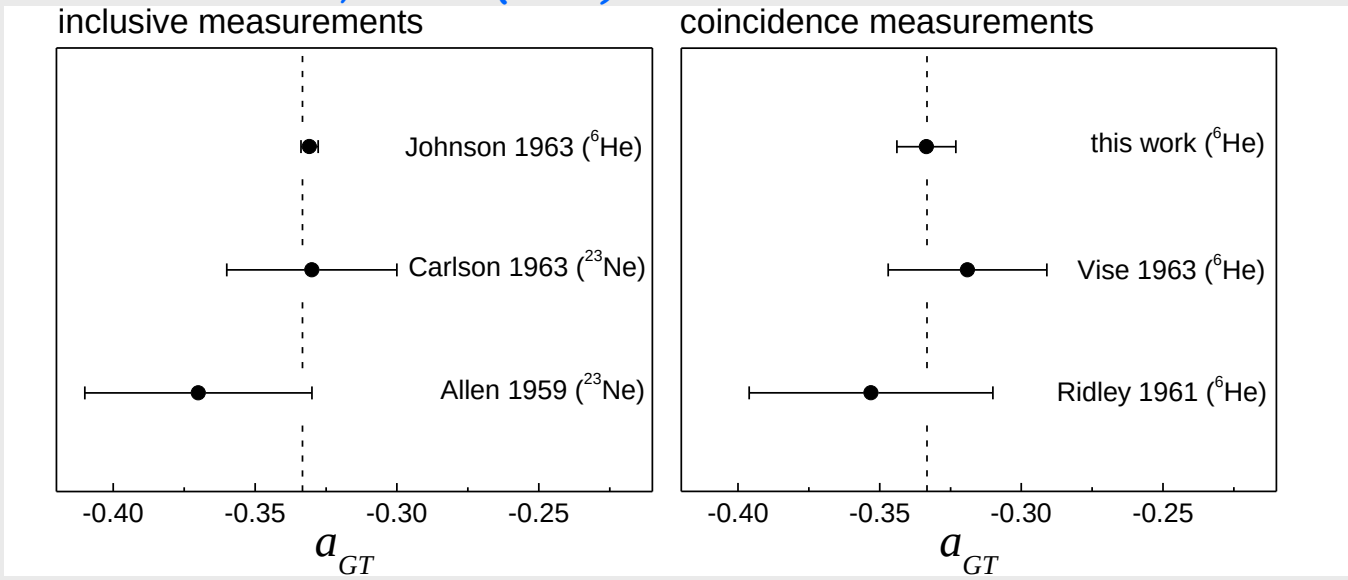

This region depends on T° and not on a

- Best value for GT & coincidence measurements
- High confidence level (check list of measured parameters)
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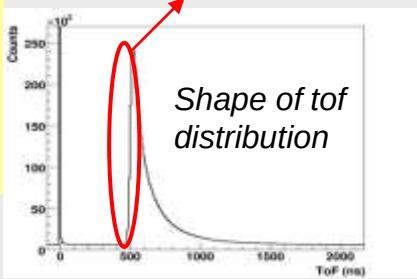
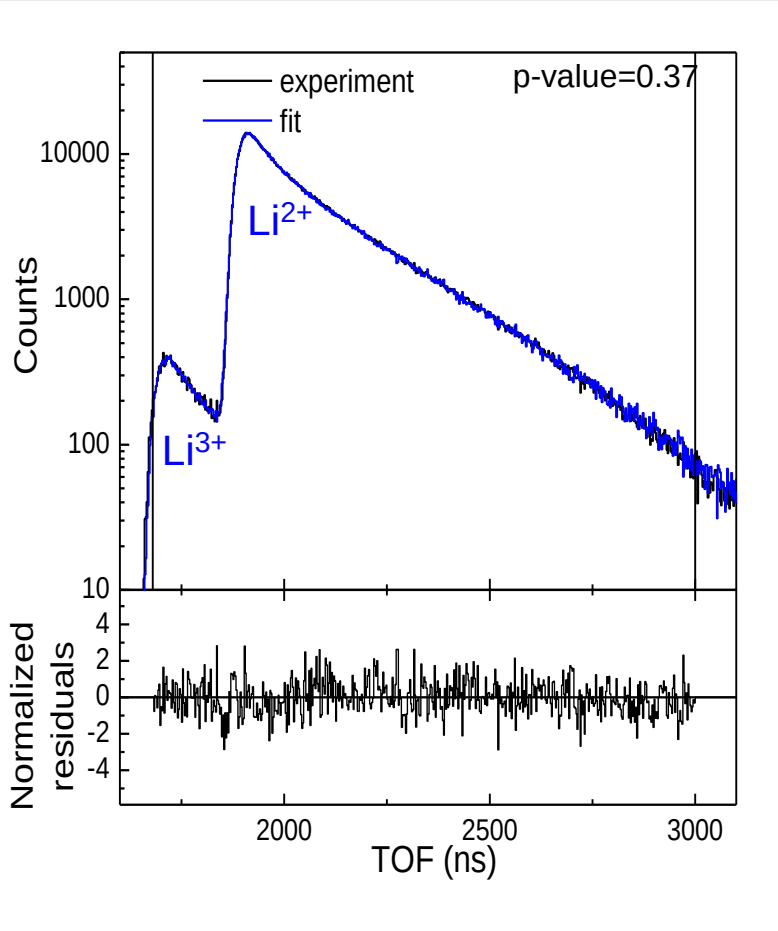


^{6}He : to constrain T current contribution

- November 2010 : 2x10^6 good events → $(\sigma_a/a)_{stat}$ ~ 0.5% ok!



- Shake-off probability

  $P_{shake\text{-}off}$ = 0.02339(36)

  Couratin et al., accepted in PRL

  - first measurement in ^{6}He^{1+} decay
  - realistic simulation assuming a = -1/3
  - high precision: $\Delta P_{shake\text{-}off}$ =3.6 10^{-4}
  - excellent agreement with theoretical value: (sudden approximation) P = 0.02322 (Z. Patyk & K. Siegien-Iwaniuk, Warsaw)

- Angular correlation coefficient a

  - goal reached
  - analysis is on track

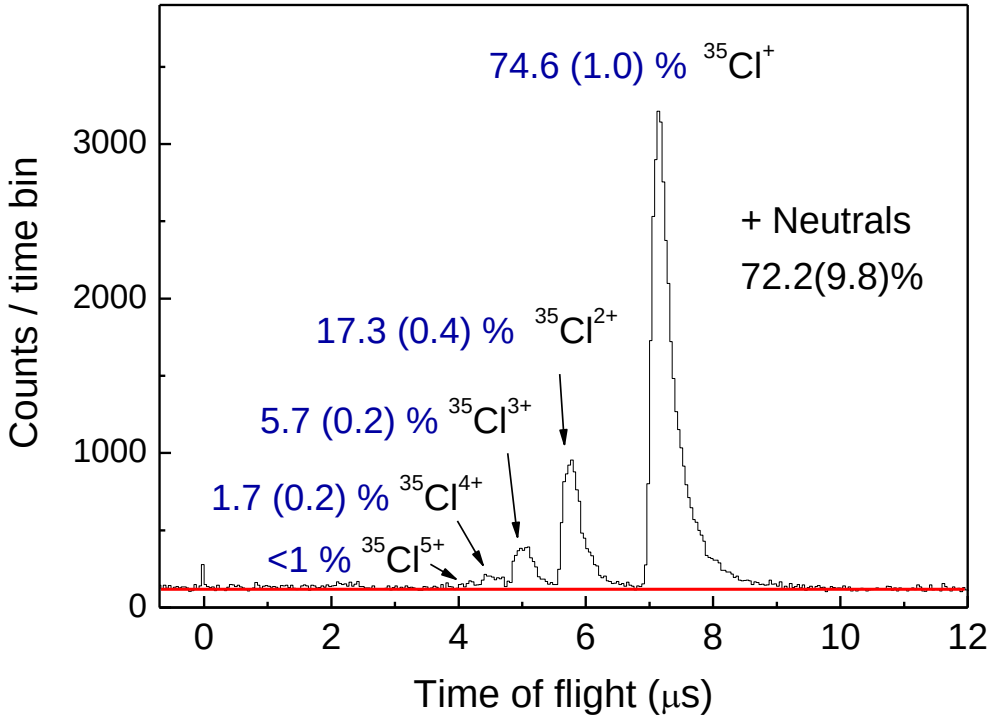
^{35}Ar : to test CVC hypothesis & CKM unitarity

(Mirror transition : 93% F + 7% GT)

- June 2011 : commissioning run → ~ $4x10^4$ good events in 32 h with $< I_{beam} >$ ~ $1x10^7$ pps

- First result
  - charge state distributions (shake-off)
    → *useful for the WITCH experiment*
- Correlation measurement
  - quick analysis
    → $\sigma_a/a = 0.011$ (stat)

⇨ $(\sigma_a/a)_{stat}$ ~ 0.003 *reachable in 1 week*



C. Couratin et al., in preparation

Proposal accepted

Experiment scheduled in June 2012

Conclusion

LPCTrap

- is a universal setup in operation to measure β–recoil coincidences
- is able to reach a relative precision on a at the level of 0.5 %
- enables the measurement of charge state distributions of recoils, obtained for the first time in $^{6}He^{1+}$ & $^{35}Ar^{1+}$ decays

Outlook

Achievement of systematic measurements of a @ GANIL

Project over 10-15 years

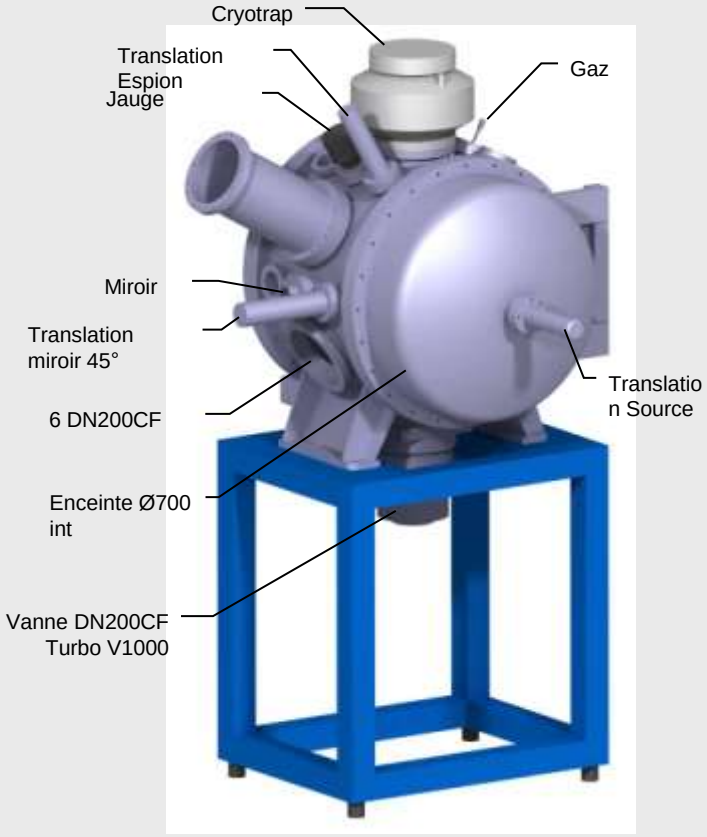
- with a precision at the level of 0.1%
- in decays of interesting radioactive nuclei provided first by SPIRAL and later by SPIRAL2

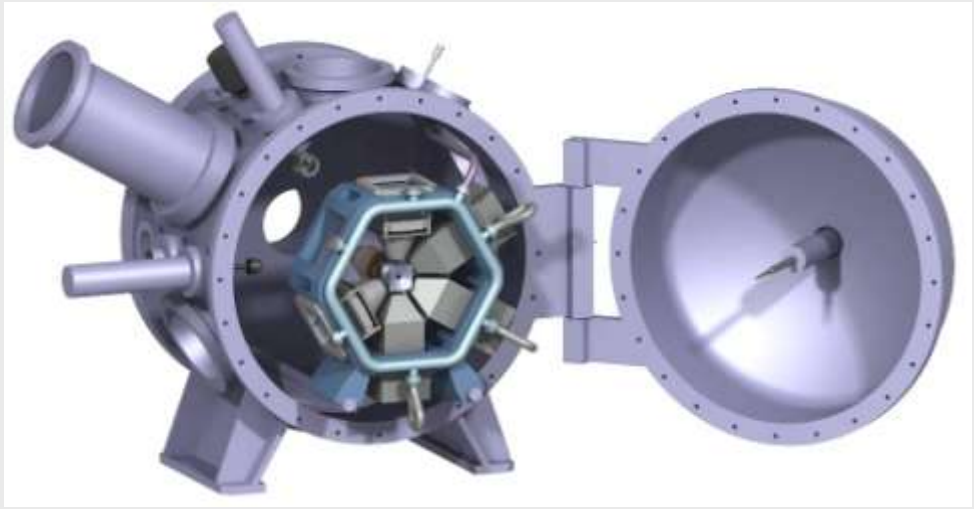
⇨ to drastically improve the constraints on exotic currents in the most general way

⇨ to test the CVC hypothesis & CKM unitarity with mirror transitions

Measurement of *a* with a precision at the level of 0.1%

⇒ *Improve the precision by rising the number of detectors*





- new chamber
- new β detector (phoswiches)
- new digital DAQ (FASTER@LPC)

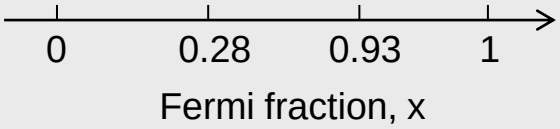
⇒ At least a factor of 10 in statistics is reachable

Systematic measurements of *a* @ GANIL

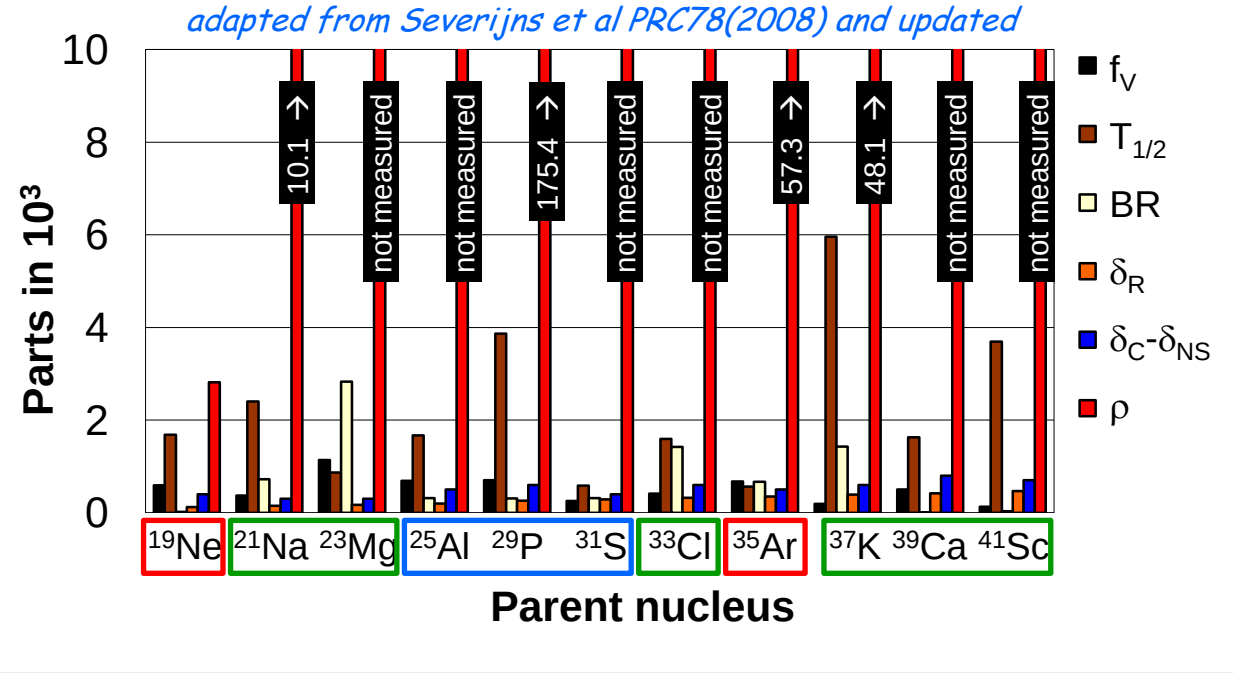
⇒ Constraints on exotic currents : in the most general way

$a\ (C_V, C_S, C_A, C_T)$

^{6}He, ^{19}Ne, ^{35}Ar, ^{34}Cl



⇒ Test the CVC hypothesis & CKM unitarity with mirror transitions: $a\ (\rho)$



SPIRAL/ Available

SPIRAL/ Upgrade

SPIRAL 2

SPIRAL/ Available | SPIRAL/ Upgrade* | SPIRAL 2

Isotope	Beam intensity (pps)	Situation	Transition type	a_{SM}	Fermi fraction x
^{6}He	2x10^{8}	Available	Pure GT	-1/3	0
^{19}Ne	1.5x10^{8}	Available	Mirror	0.0435	0.28
^{21}Na	7.3x10^{8}	Production test	Mirror	0.5587	0.67
^{23}Mg	> 2.7x10^{7}	Production test	Mirror	0.6967	0.77
^{25}Al	7.4x10^{7}	Estimated (SPI2)	Mirror	0.4818	0.61
^{29}P	1.3x10^{9}	Estimated (SPI2)	Mirror	0.7154	0.79
^{31}S	2x10^{8}	Estimated (SPI2)	Mirror	0.719	0.79
^{33}Cl	~ 10^{7}	Production test	Mirror	0.8848	0.91
^{34}Cl	4.1x10^{7}	Production test	Pure F	1	1
^{35}Ar	4x10^{7}	Available	Mirror	0.9004	0.93
^{37}K	1.2x10^{8}	Production test	Mirror	0.658	0.74
^{39}Ca	1.3x10^{5}	Calculated	Mirror	0.6036	0.70
^{41}Sc	1x10^{5}	Calculated	Mirror	0.297	0.47

** : First beams expected in 2013 / See P. Delahaye for details*

Systematic measurements of *a* @ GANIL

⇒ Constraints on exotic currents : in the most general way

$a\ (C_V, C_S, C_A, C_T)$

^{6}He, ^{19}Ne, ^{35}Ar, ^{34}Cl

0 — 0.28 — 0.93 — 1

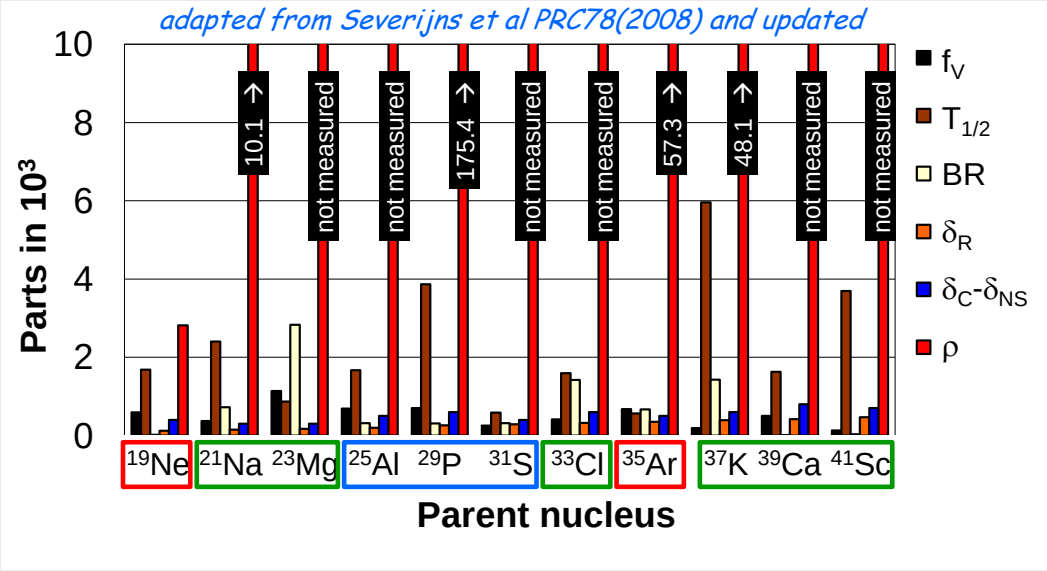
Fermi fraction, x

⇒ Test the CVC hypothesis & CKM unitarity with mirror transitions: $a\ (\rho)$

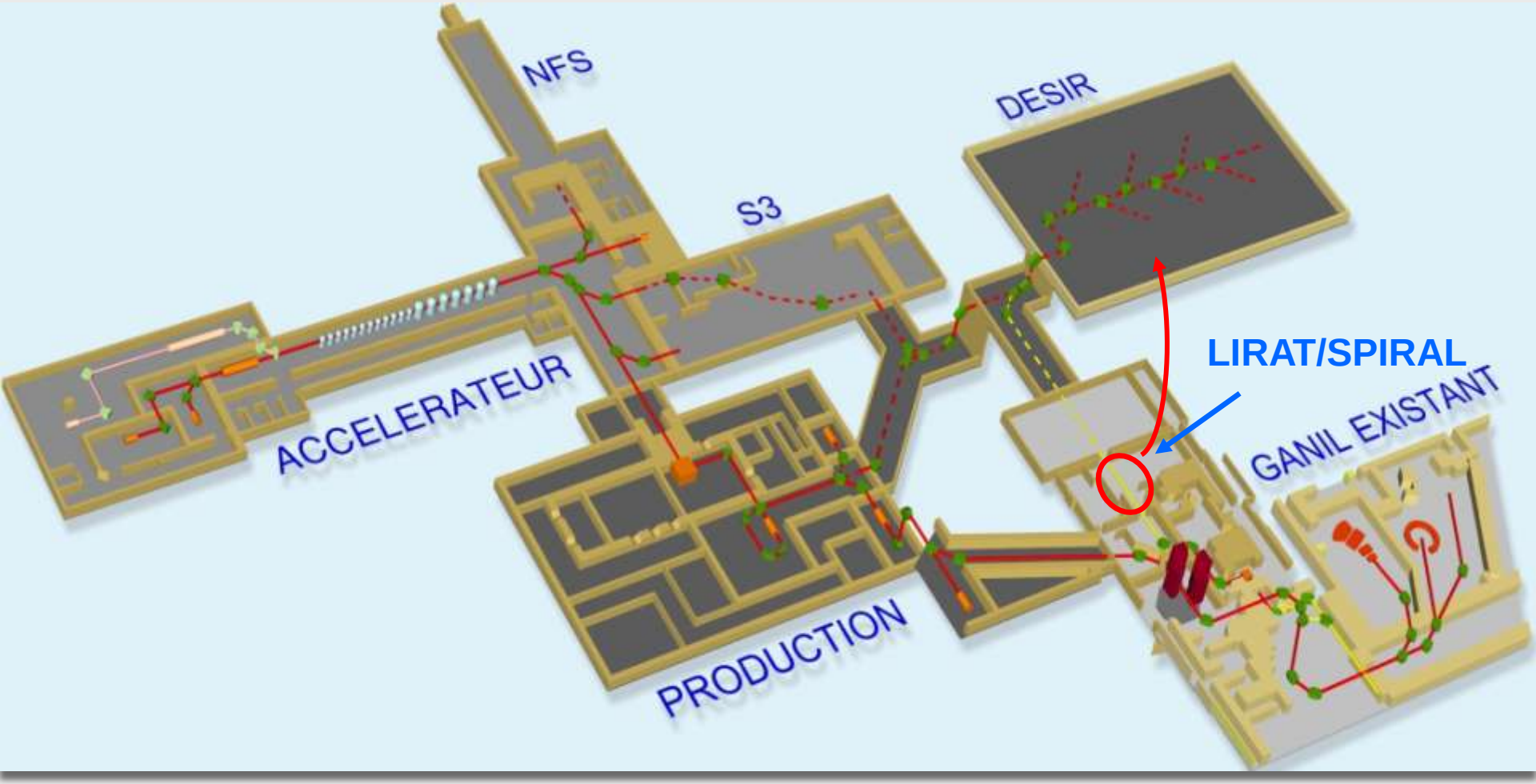
SPIRAL/ Available — SPIRAL/ Upgrade — SPIRAL 2

2012 - 2016(?)
LPCTrap @ LIRAT

> 2016(?)
LPCTrap @ DESIR



LPCTrap installed @ DESIR in 2016 ?



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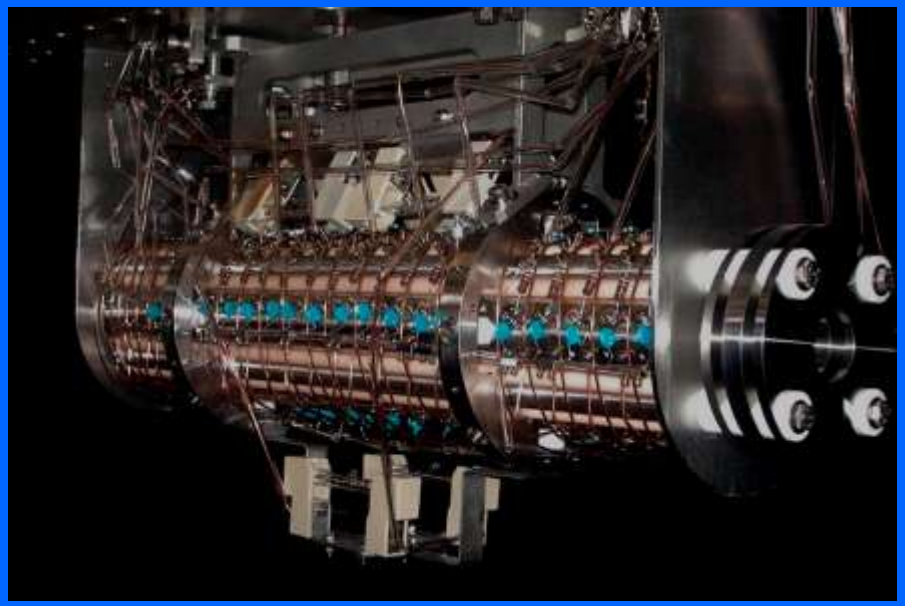

And the LPC technical staff ….