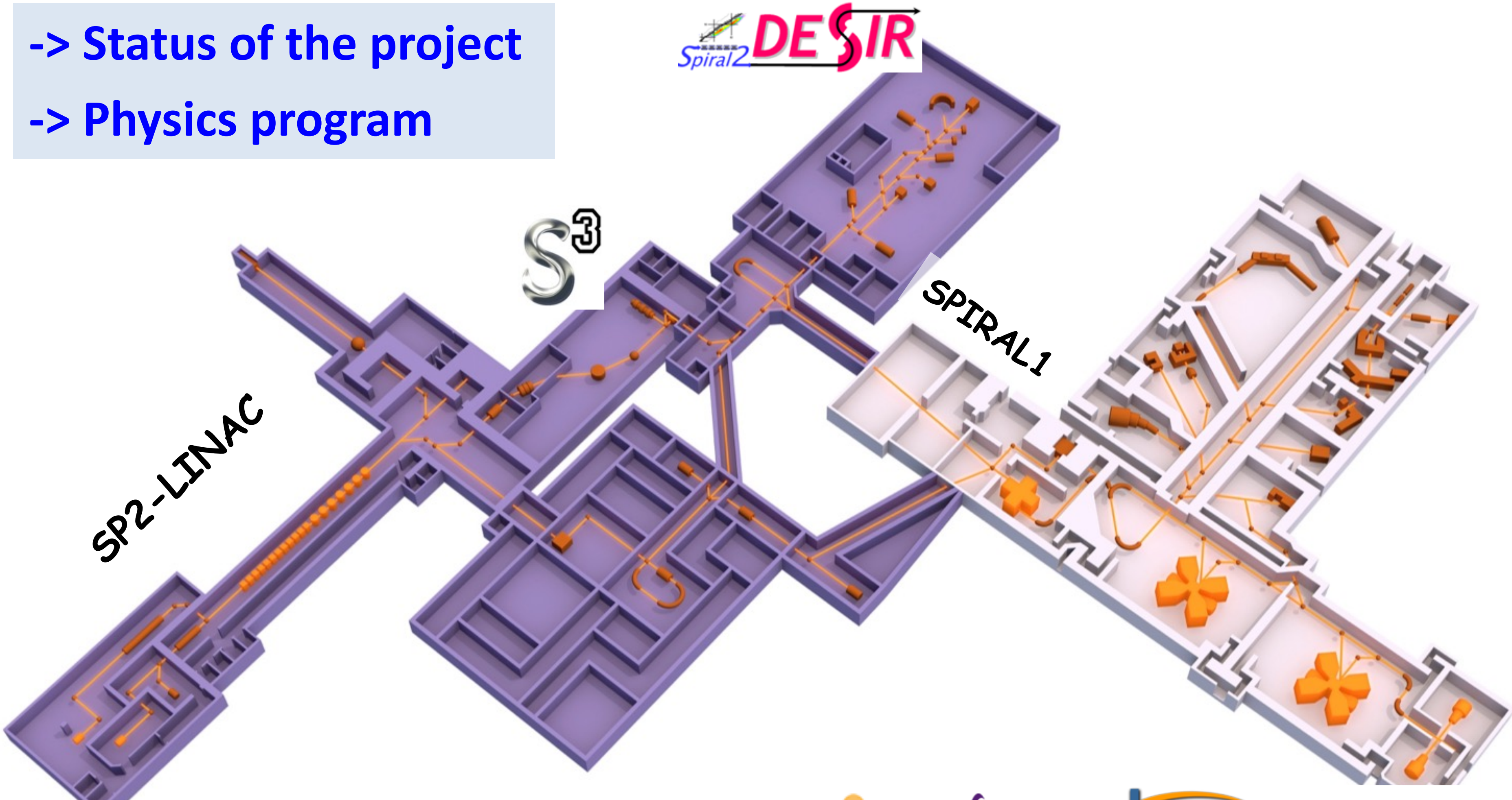
DESIR: Timeline & Physics program

Désintégration, Excitation et Stockage d'Ions Radioactifs

http://pro.ganil-spiral2.eu/spiral2/instrumentation/desir

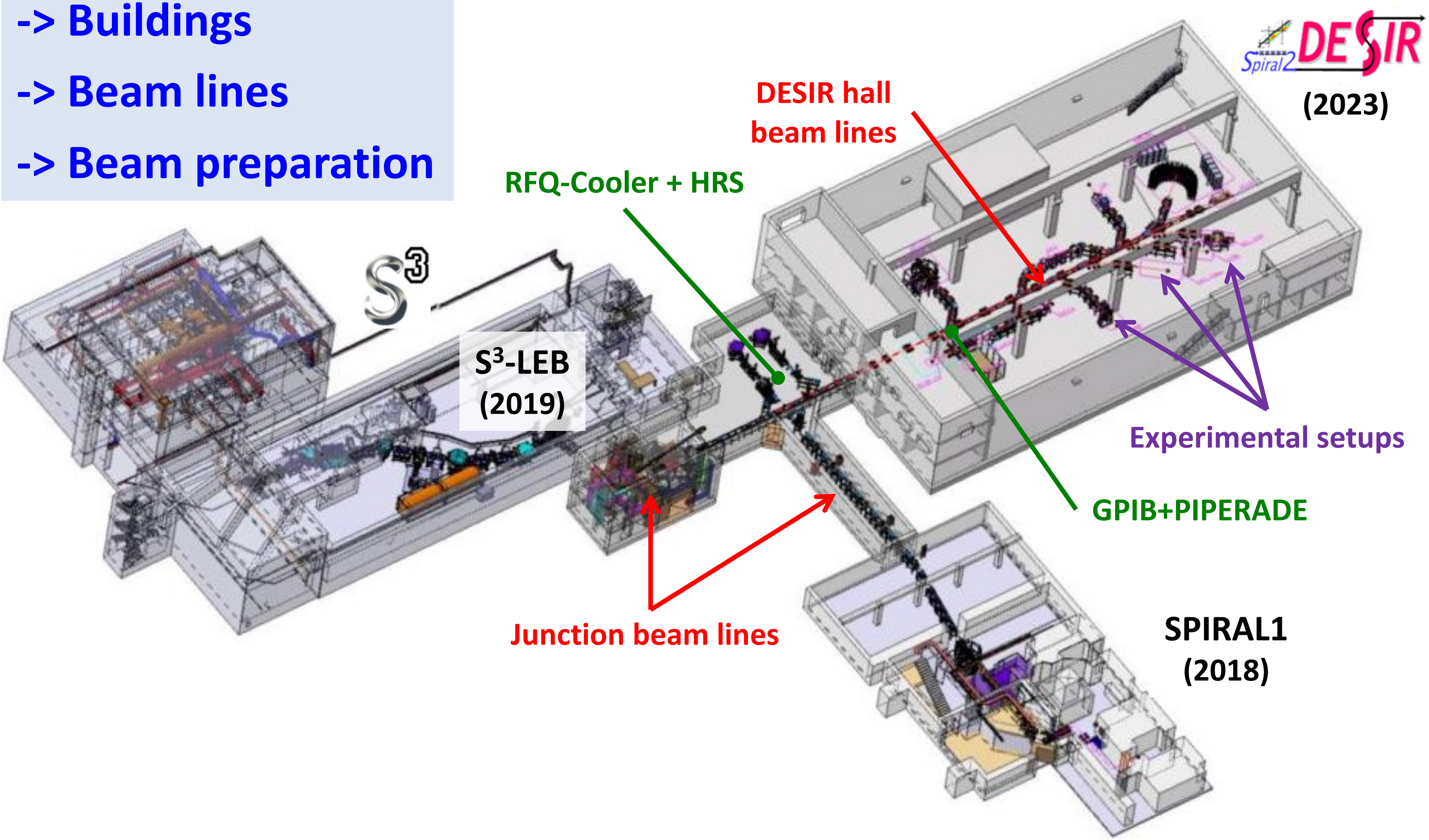
-> Status of the project

-> Physics program



DESIR: Status of the project

- -> Timeline
- -> Buildings
- -> Beam lines
- -> Beam preparation



DESIR: Timeline

Historical perspective

- 2005: SP2 workshop on low-energy physics with SPIRAL(2) beams -> DESIR coll. formed
- 2006: LoI submitted to the SP2 SAC
- 2008: Technical design report (111 scientists / 35 institutes / 15 countries) -> 2013

  -> Management, Equipment, Buildings, Safety rules
- 2011: (Very) preliminary design study of the facility within the SPIRAL2 project

  21 LoI submitted: ¼ S1, ½ S2, ¼ S^3 beams -> 2015

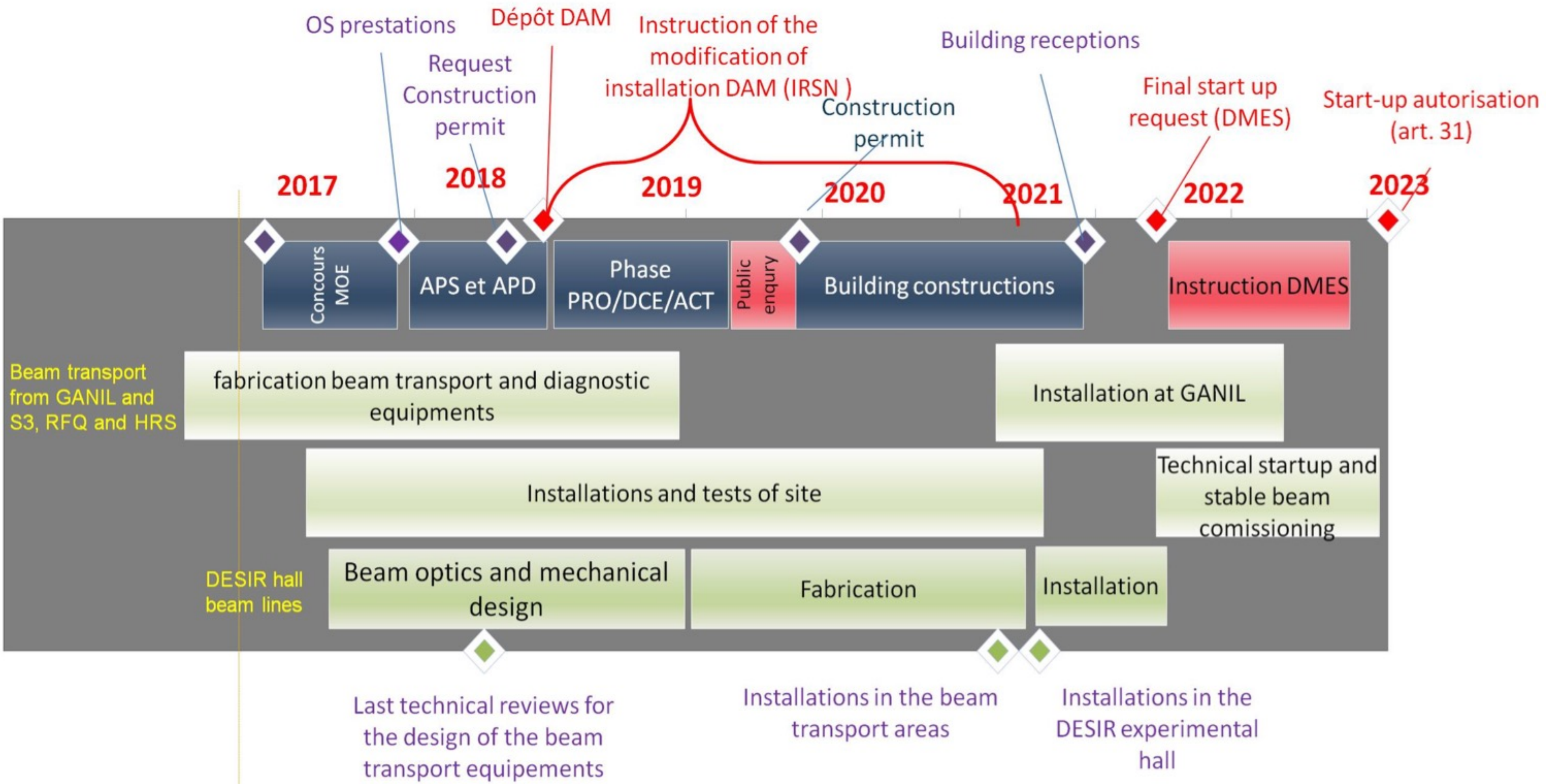
  DESIR EQUIPEX funding: 8 M€ (->2020)
- 2012: DECA (Desir Collaboration Agreement) signed -> commitment of future users to operate experimental equipment at DESIR (~5 M€ investment)
- 2013: Decision to postpone the Phase 2 of SPIRAL2; DESIR == SPIRAL2 Phase 1+ -> 2017/2018
- 2014: DESIR/S^3-LEB workshop -> LoI update: ½ S1, ½ S^3 beams

  Preliminary design update (cost estimate ~ 24 M€)
- 2015: Budget secured (ANR, GSI-FAIR , CNRS, Région Basse Normandie)

  Decision to go through a dedicated safety licensing of the facility -> 2021
- 2016: Decision to launch a new call for tender for the facility study/construction

-> 2023

DESIR: Timeline (2016)

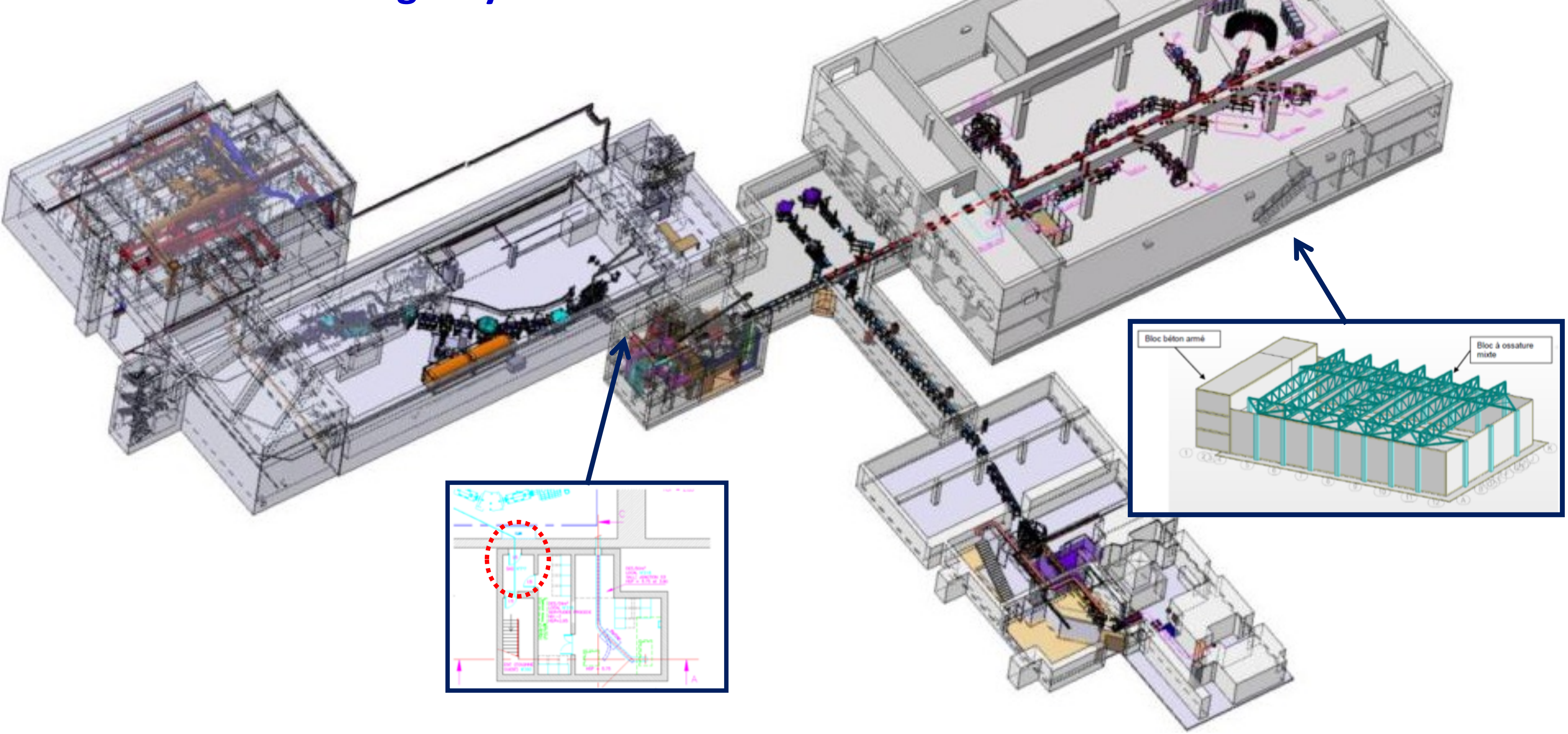


- **Ok with respect to beam lines and beam preparation equipment**
- **Concern with respect to the building construction and the safety licensing: 6 months delay anticipated (GANIL manpower issues)**

DESIR: Buildings

Preliminary design (2014 -> 2016)

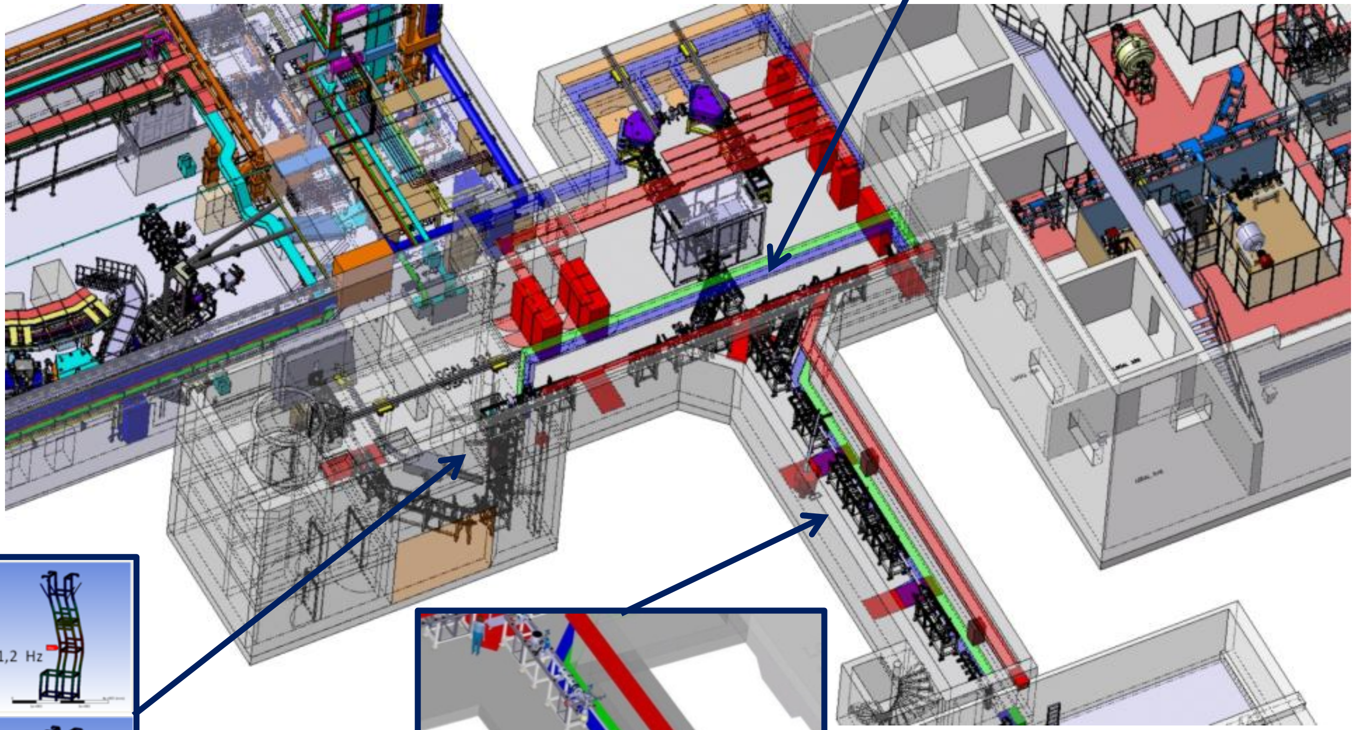
- Optimized-> starting point for the new call for tender
- Technical solution proposed to avoid pillars
- Includes an emergency exit from the S^3 hall

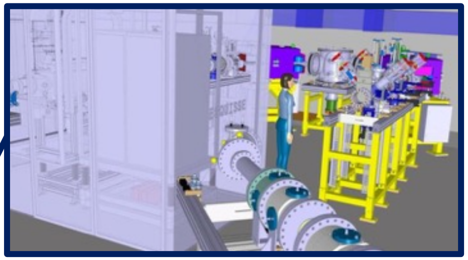


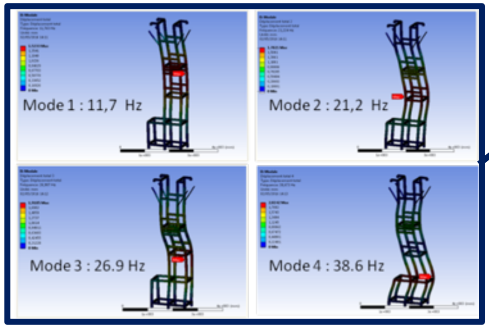
DESIR: Buildings

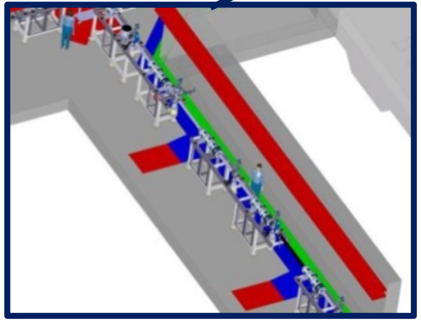
Process integration

- Servitudes and utilities (remote control, power supplies, fluids, …)
- Accesses/circulation/interfaces
- Equipment maintenance
- Seismic studies





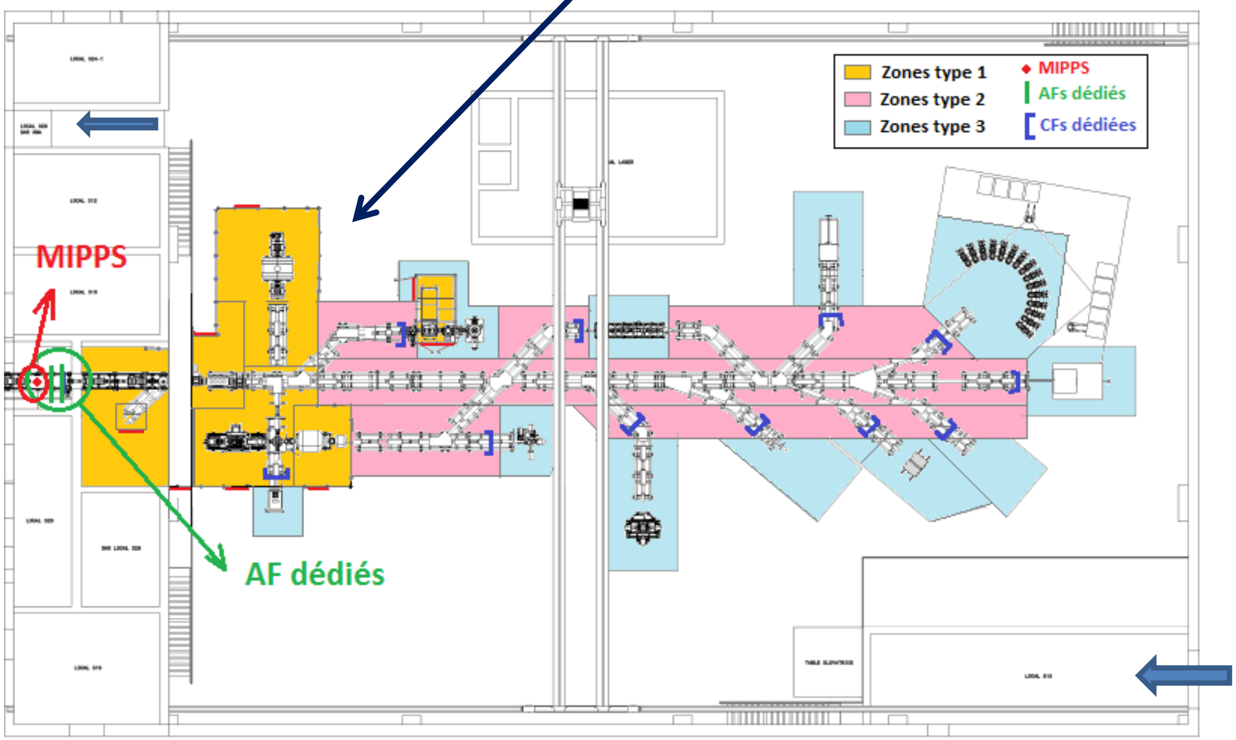




DESIR: Buildings

Operation conditions

- Accessibility
- Equipment maintenance
- (general) Safety constraints



-> Towards detailed operation rules (+ (general) safety equipment specifications)

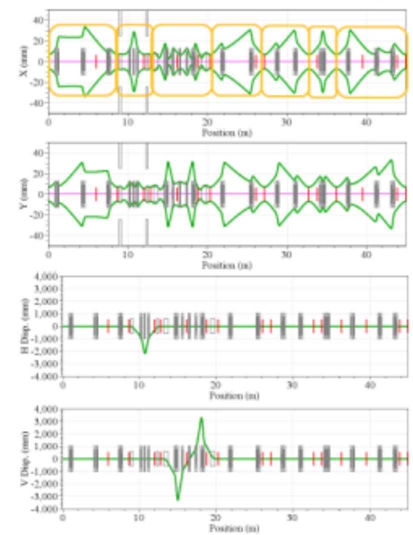
DESIR: Beam lines

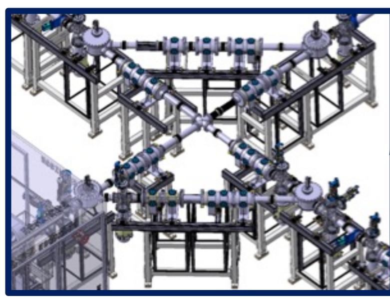
From optical studies to mechanical design studies

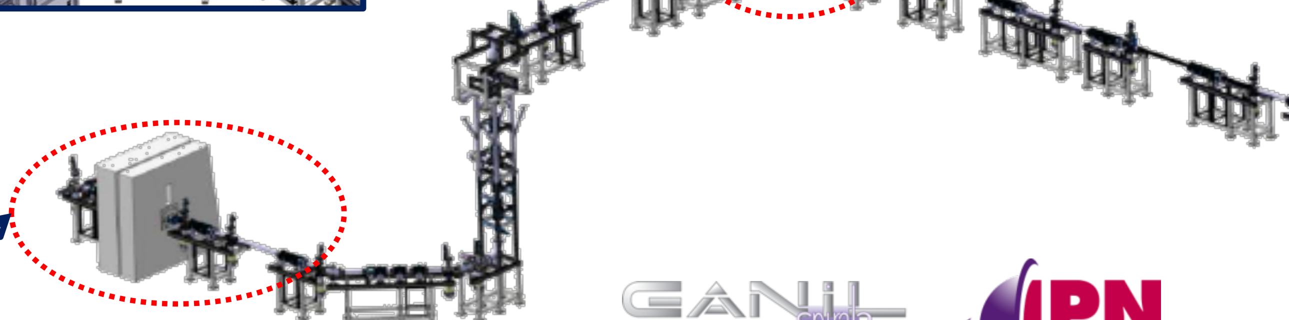
- Full design of the junction beam lines
  - from S^3-LEB to DESIR (45 m)
  - from S1 to DESIR (50 m)
- Electrostatic equipment, point-to-point transport
- Integration of supplies and utilities inside de mechanical structure

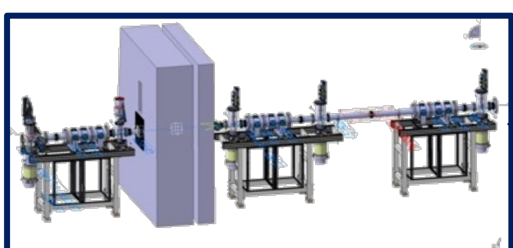
3-80 π.mm.mrad
10-60 keV
Q=1+

➢ From S3-LEB to DESIR hall (45m)







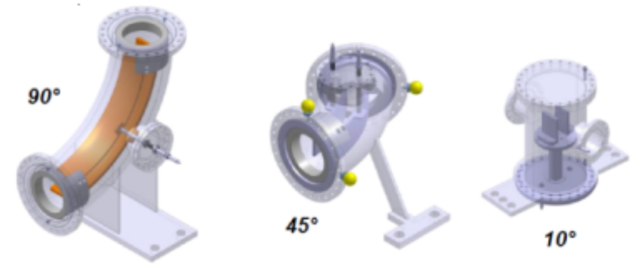


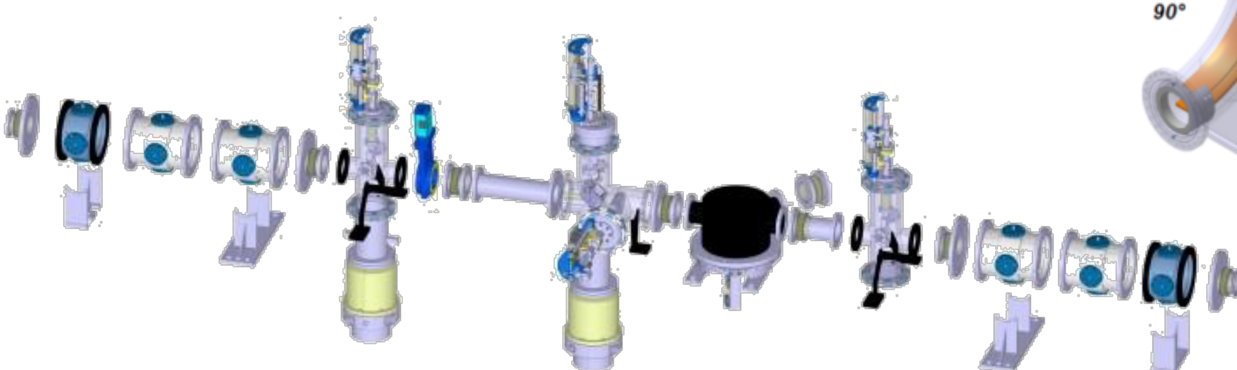
DESIR: Beam lines

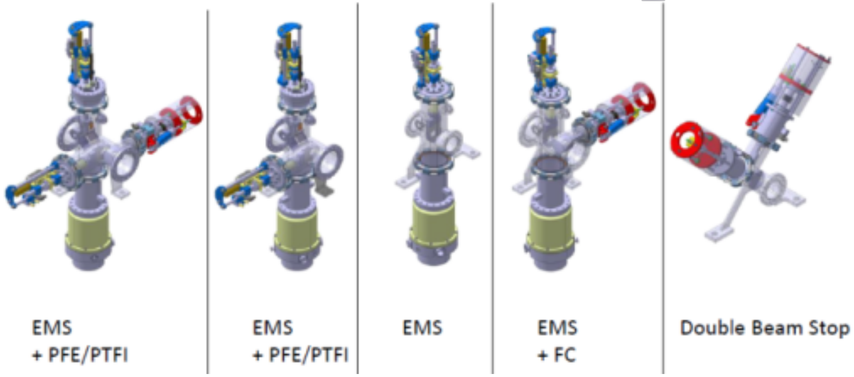
From design studies to manufacturing

- Standardization of beam line equipments: diagnostics, pumps, …

-> towards final specifications and manufacturing (->2021)





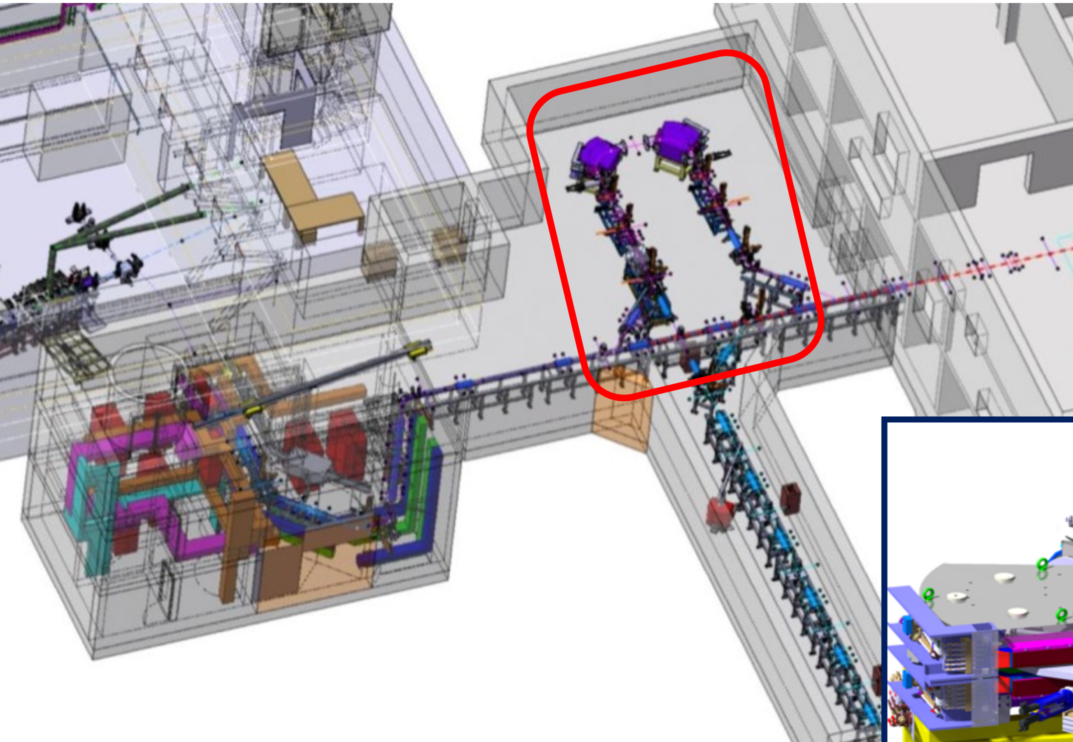


-> Exp. hall beam lines yet to be studied

DESIR: Beam preparation

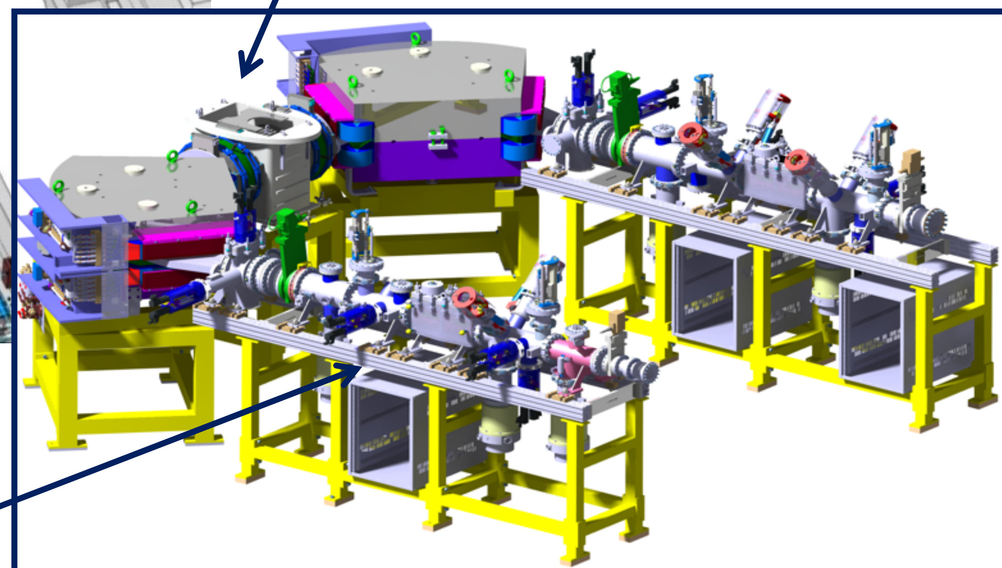
High resolution separation: RFQ1P + HRS1P

-> M/ΔM ~20000 at 60 kV, 3 π.mm.mrad, eμA (ΔE ~1 eV)



HRS1P

T. Kurtukian Nieto et al., NIMB 317 (2013) 284



RFQ1P

R. Boussaid et al., 2014 JINST 9 P07009

DESIR: Beam preparation

High resolution separation: RFQ1P + HRS1P

-> M/ΔM ~20000 at 60 kV, 3 π.mm.mrad, eμA (ΔE ~1 eV)

RFQ1P

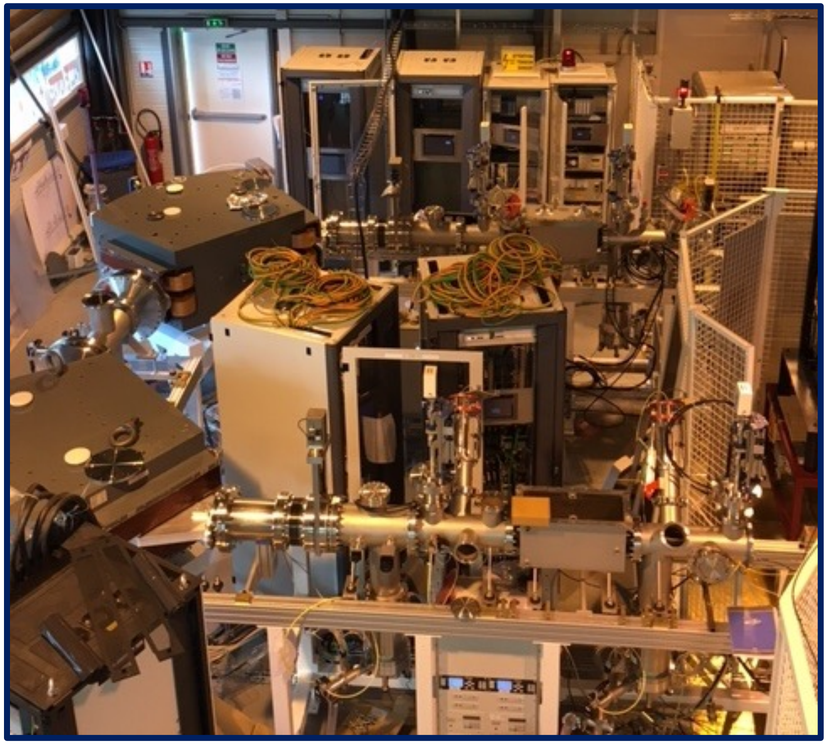
- Prototype ok: ~70 % transmission @ 1 eμA (A = 40 to 130)
- Adaptation & tests: 2017-2019

RFQ cooler

Baie des équipements de contrôle du RFQ cooler

HRS1P

- Assembly, C/C, utilities: 2017
- Tests and optimizations: 2017-2020

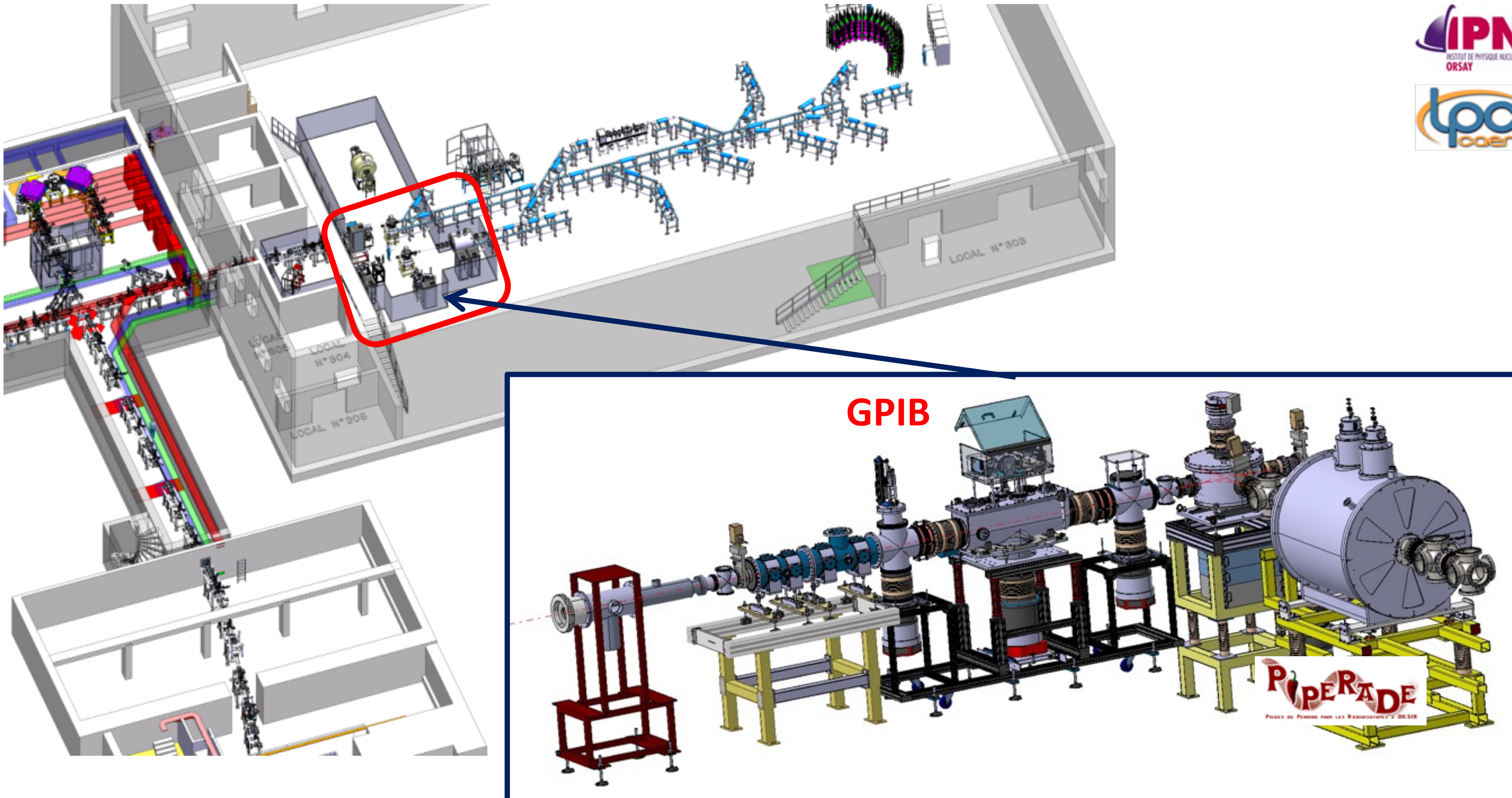


-> Installation at DESIR: 2021

DESIR: Beam preparation

General Purpose Ion Buncher (and Cooler) + PIPERADE

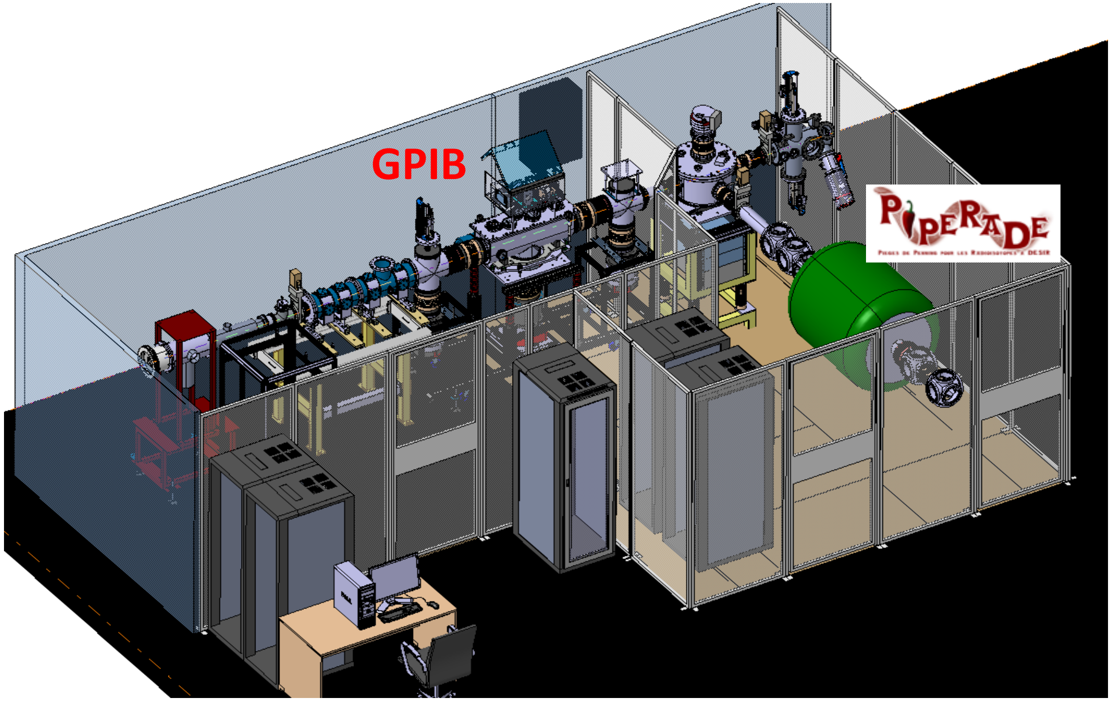
- Cooling and bunching before the beam is sent to the experimental setups
- Purification with a “high intensity” double Penning trap (-> 10^5 pps/bunch)

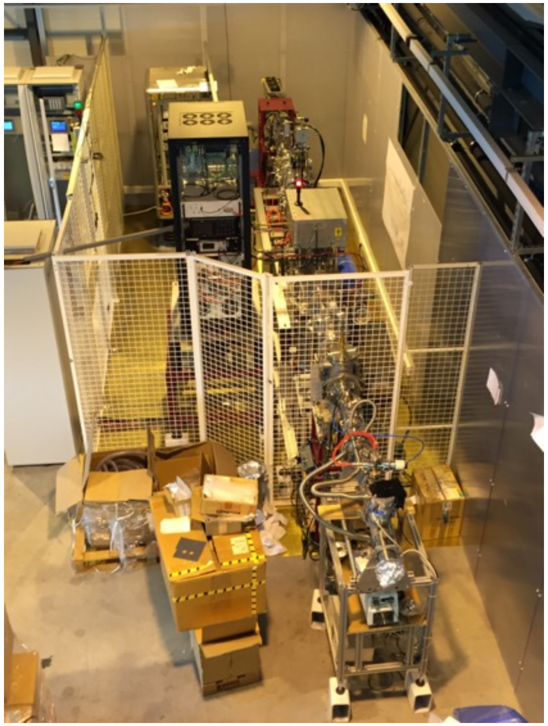


DESIR: Beam preparation

General Purpose Ion Buncher (and Cooler) + PIPERADE

- **GPIB commissioning ongoing** (~80% transmission for A=40, 4.5 π.mm.mrad @ 30 keV)
- **Assembly and coupling of the PIPERADE double Penning trap in 2017**
  - -> Magnet delivery in May; 1st beam from GPIB by the end of 2017





-> Plans to use PIPERADE at SPES before installation at DESIR (2022)

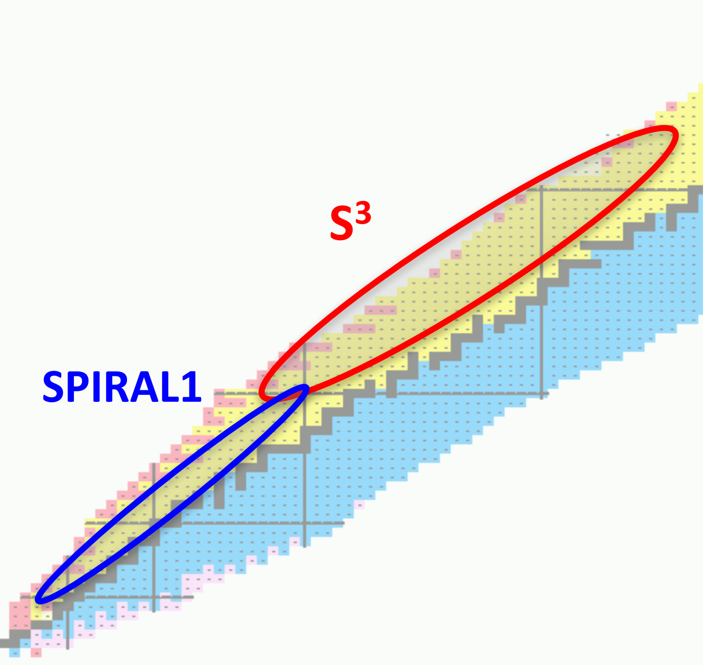
DESIR: Physics program

Physics with low-energy radioactive ion beams

- Decay properties (ground & long lived isomeric states)
- Nuclear structure & deformation
- Fundamental interactions

Ultra-pure samples for high precision measurements

Day-1: "light" neutron-deficient nuclei from SPIRAL1 and S^3



Complementary techniques

- (Trap-assisted) decay spectroscopy
- Collinear laser spectroscopy
- Mass measurements
  - -> Talk by P. Ascher on Thursday

-> 3 groups of experimental setups

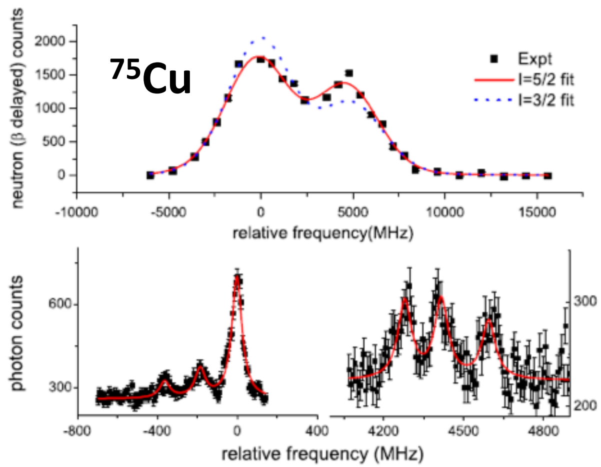
BESTIOL, LUMIERE, DETRAP

DESIR: High-resolution laser spectroscopy

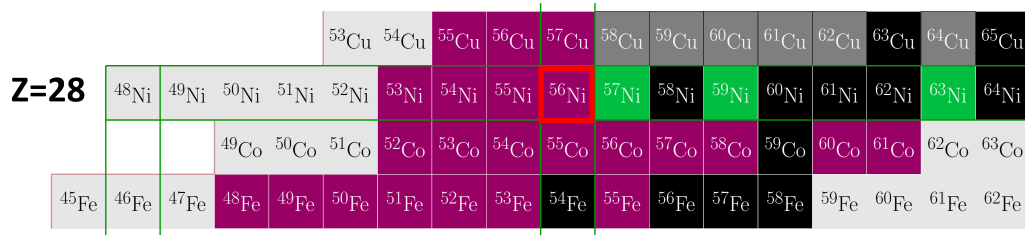
Two complementary laser spectroscopy lines:

- **CRIS (Collinear Resonant Ionization Spectroscopy) – ISOLDE** (G. Neyens, M. Bissel)
  - -> nuclear structure and deformation (I, μ, Q, <r^2>)
  - ✓ high-resolution spectroscopy (20-50 MHz) at low rate (>20/s)

K.T. Flanagan et al., PRL 103 (2009) 142501



✓ Doubly-magic nature of N,Z=28?
-> n-deficient Fe to Cu isotopes (S1, S^3)



N=28

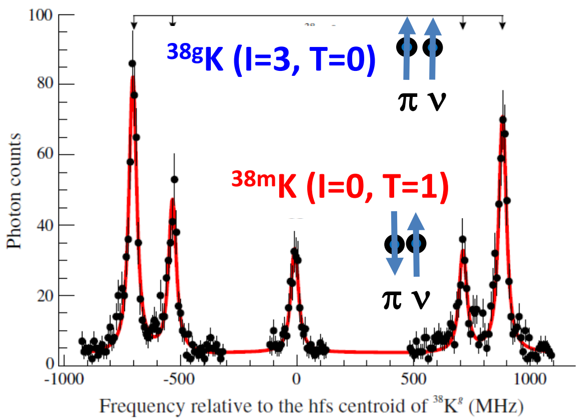
T.E. Cocolios

- **LINO (Laser Induced Nuclear Orientation) – ALTO** (D. Yordanov)
  - -> nuclear structure of parent (g-factor, Q) and daughter (J^π) nuclei
  - ✓ β-NMR/NQR of laser-polarized ions and β–γ asymmetry (> 100-1000/s)

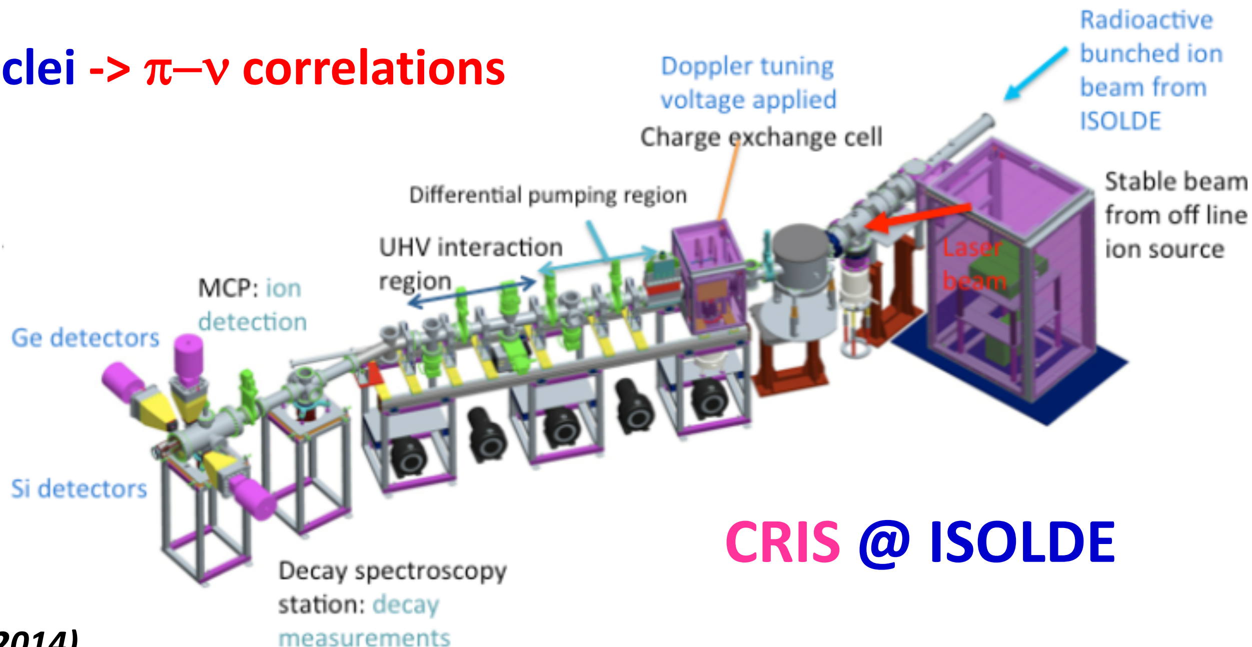
IKS, IPNO, Univ. Manchester

DESIR: High-resolution laser spectroscopy

✓ Isomer shift of N=Z<50 nuclei -> π–ν correlations
G. Neyens



M.L. Bissell et al., PRL 113, 052502 (2014)



-> study of the self-conjugate nuclei ^{52}Fe (S1,S^3), ^{54}Co and ^{70}Br (S^3)

✓ ^{100}Sn region (S^3): μ, Q that may not be accessible with the in-gas jet laser spectroscopy technique (HFS <100 MHz) – M.L. Bissel

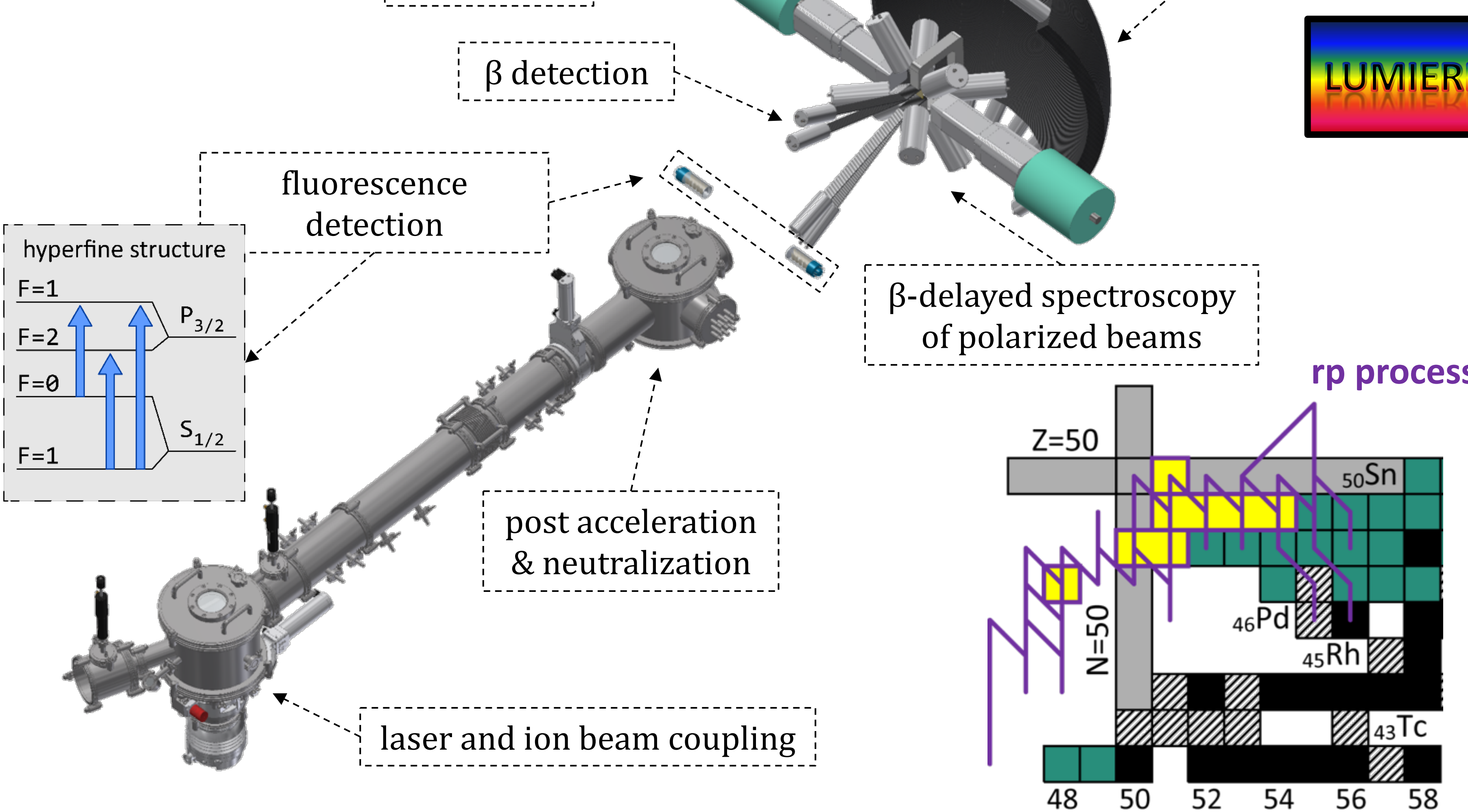
✓ n-deficient Sr, Y, Zr (S^3) – P. Campbell

LUMIERE

DESIR: β-decay of laser-polarized ions

LINO @ ALTO

D. Yordanov



✓ **Decay spectroscopy of ^{95}Ag, ^{101}Sn; g.s. properties of $^{100\text{-}103}$In, $^{98\text{-}99}$Cd (S^3)**

DESIR: Beta decay studies

BESTIOL

Total absorption spectroscopy (J.L. Tain, A. Algora, B. Rubio)

^{100}Sn and ^{80}Zr regions (S^3)

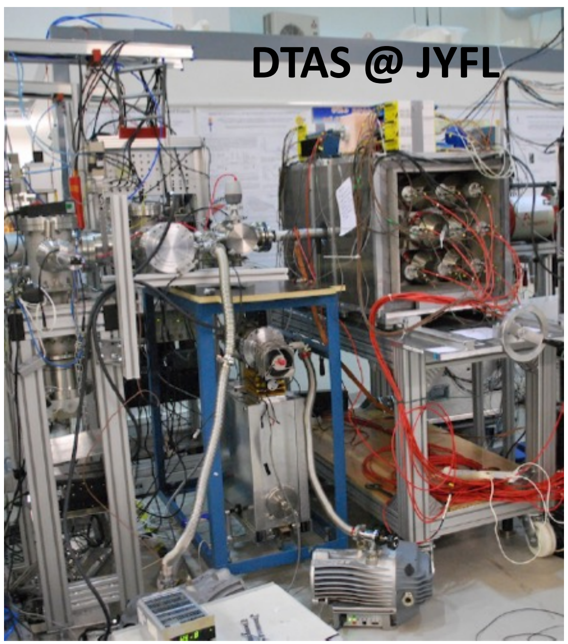
-> nuclear structure (level density, J$^\pi$)

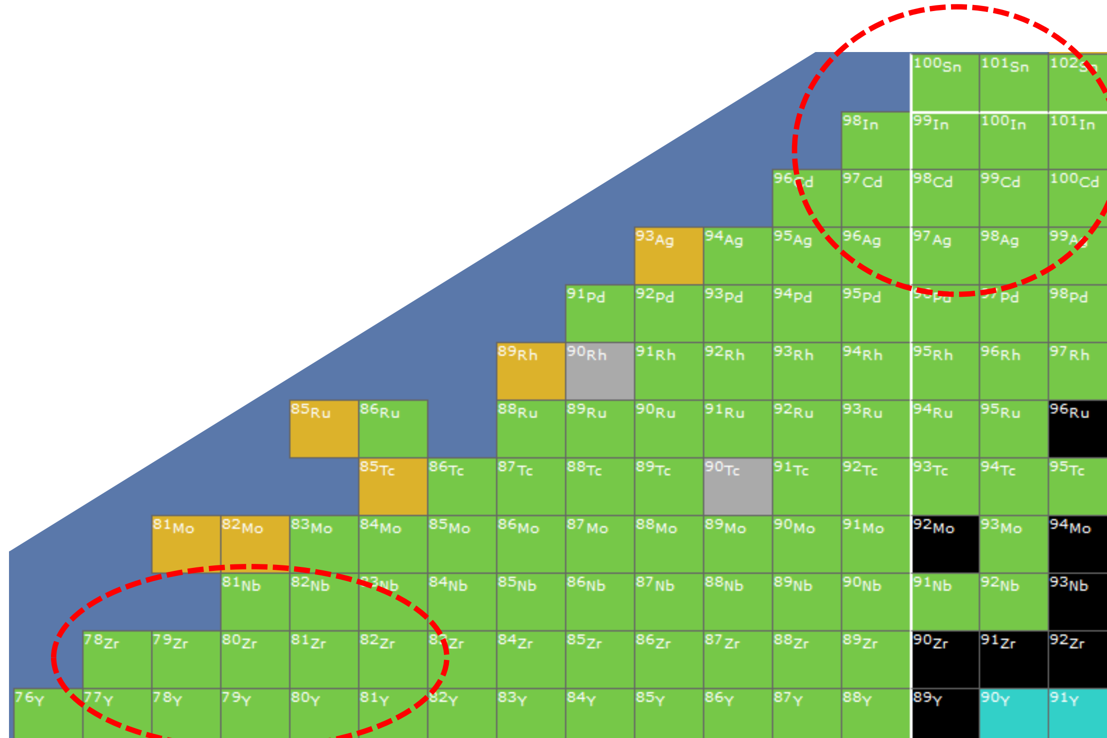
-> deformation

-> GT strength distribution/quenching

-> Complementary to decay and laser spectroscopy at S^3-LEB

-> PIPERADE (cleaning) + DTAS





IFIC, CIEMAT, Univ. Surrey, ATOMKI, IEM, CENBG, GANIL

DESIR: Beta decay studies

Spiral2 DESIR

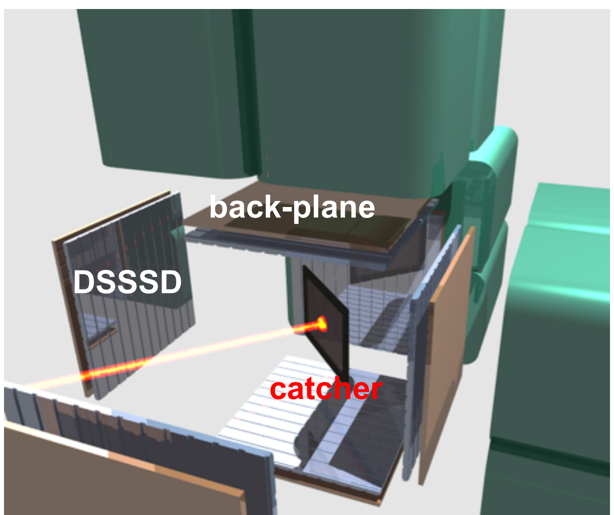
BESTIOL

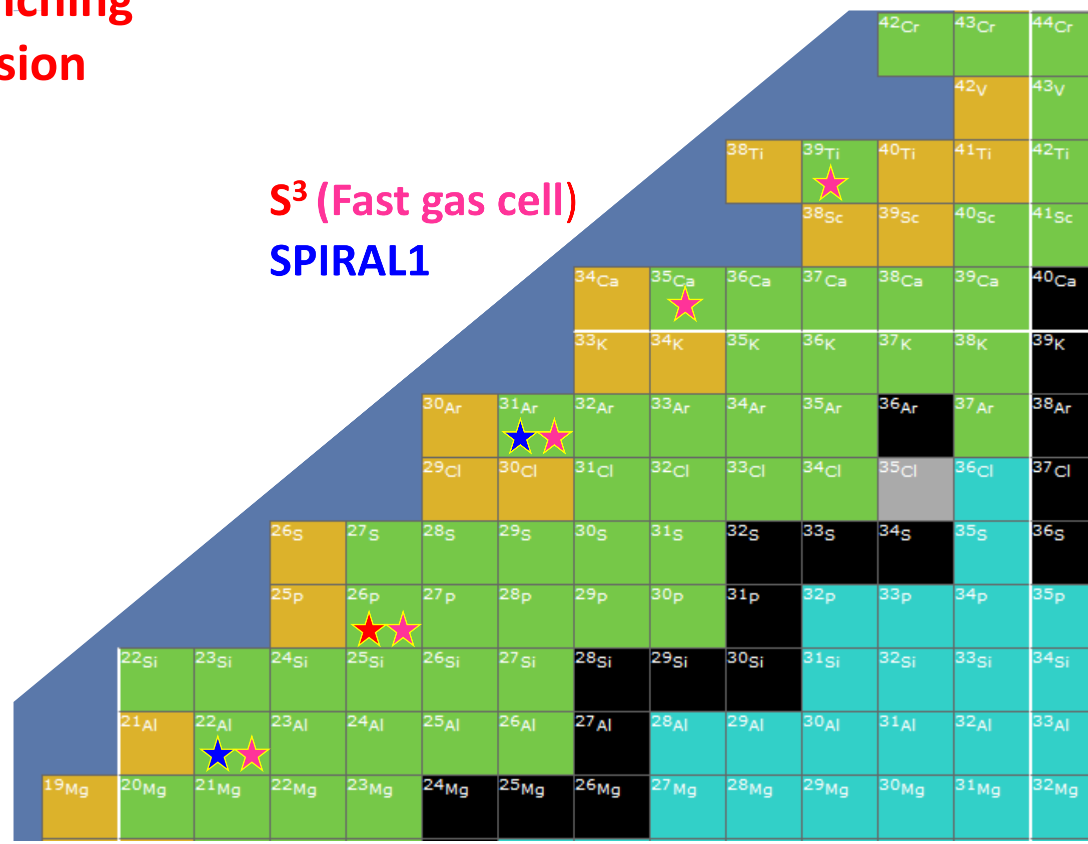
β-delayed charged particle emission

- -> nuclear structure (spectroscopy, masses <-> IMME)
- -> astrophysics inputs ($\Gamma_{p,\gamma}$ <-> (p,γ) reactions)
- -> isospin mixing (β-xp from IAS)
- -> GT strength distribution/quenching
- -> search for correlated 2p emission
- -> study of exotic decay modes

-> SiCube: η_p = 60%, η_{2p} = 30%

I. Matea et al., NIM A 607 (2009) 576



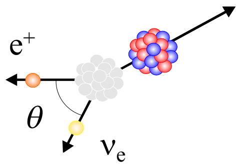


CENBG, GANIL, JYFL, CSIC, IPNO, Univ. Aarhus

DESIR: Physics program

Fundamental interaction studies

DETRAP



- **High precision β-decay measurements**
  - ✓ 0+ -> 0+ super-allowed Fermi transitions: T_z = 0, -1, -2 nuclei
  - ✓ Mirror transitions: T_z = -1/2 nuclei

    -> Modelization of isospin non-conserving effects

    -> Unitarity test of the CKM quark-mixing matrix

- **β–ν correlation coefficient measurements**

Polarization

$$dW \sim 1 + a\frac{\vec{p}_e\cdot\vec{p}_\nu}{E_eE_\nu} + b\Gamma\frac{m}{E_e} + \frac{\vec{I}}{I}\cdot\left[A_\beta\frac{\vec{p}_e}{E_e} + B_\nu\frac{\vec{p}_\nu}{E_\nu} + D\frac{\vec{p}_e\times\vec{p}_\nu}{E_eE_\nu}\right]$$

-> Limits on scalar and tensor currents

-> GT/F ratio in mirror transitions

-> Right-handed currents

-> CP (T) violation

LPC Caen, CENBG, GANIL, CIMAP, IKS, KVI, LMU, MSU

DESIR: Fundamental interactions

0+ -> 0+ super-allowed Fermi transitions

DETRAP

$$\mathcal{F}t^{0^+\rightarrow 0^+} \equiv f_V t^{0^+\rightarrow 0^+}(1+\delta_{NS}^V - \delta_C^V)(1+\delta_R') = \frac{K}{2G_F^2 V_{ud}^2 C_V^2 (1+\Delta_R^V)}$$

Q_β, $T_{1/2}$, BR

Isospin symmetry breaking (< 1.5 %)

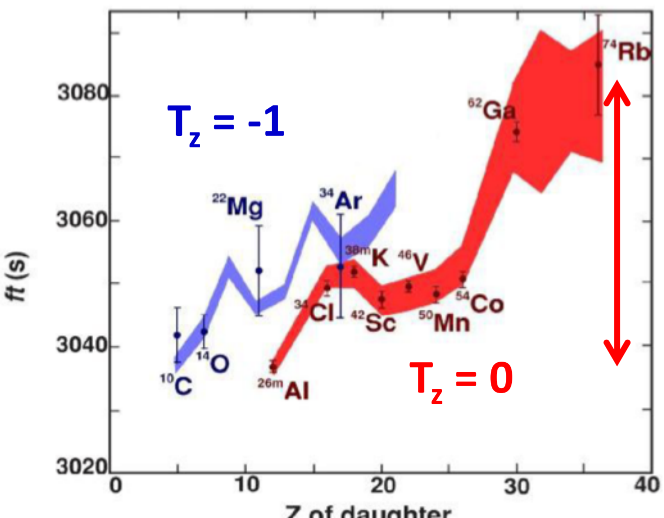
Tests of CKM unitarity

$V_{ud} = 0.97425\ (22)$

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

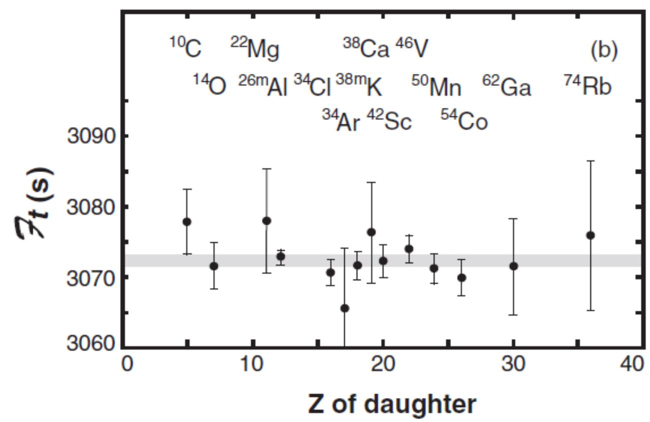
$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 0.99978(55)$

Without correction



~2%

With correction



~0.03%

J.C. Hardy and I.S. Towner, PRC 91, 025501 (2015)

-> Mass measurement to the keV precision level (MLLTrap)

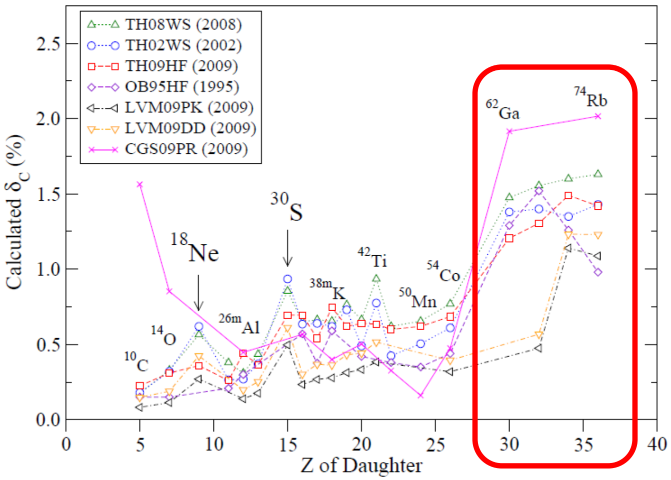
-> BR, $T_{1/2}$ to the 10^{-3} precision (PIPERADE cleaning)

DESIR: Fundamental interactions

0+ -> 0+ super-allowed Fermi transitions

DETRAP

$$\mathcal{F}t^{0^+\to 0^+} \equiv f_V t^{0^+\to 0^+}\left(1+\delta_{NS}^V-\delta_C^V\right)\left(1+\delta_R'\right)=\frac{K}{2G_F^2\,V_{ud}^2\,C_V^2\,\left(1+\Delta_R^V\right)}$$

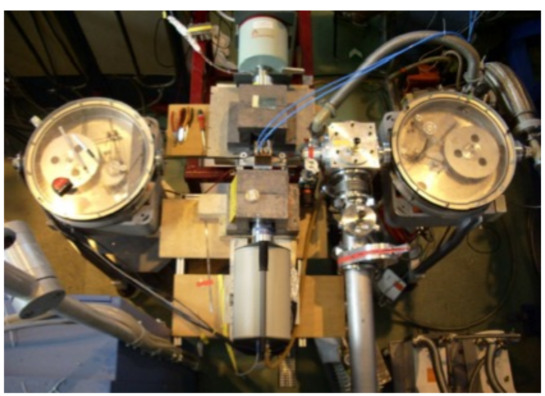


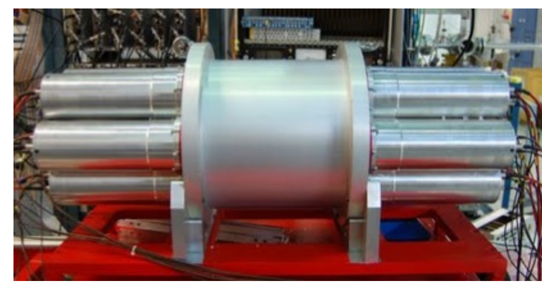
G.F. Grinyer et al., NIMA 622, 236(2010)

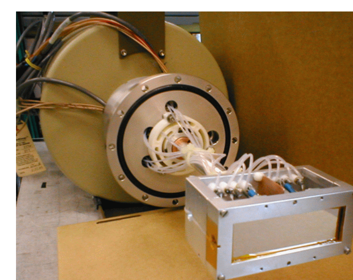
- Isospin symmetry breaking larger for high Z nuclei

-> S^3 (fast gas cell) T_z=0 beams: ^{66}As, ^{70}Br, ^{78}Y… ^{98}In
+ T_z=-1 (^{42}Ti -> ^{66}Se); T_z=-2 (^{20}Mg, ^{24}Si)

-> Complementary TAS and e^- spectroscopy measurements





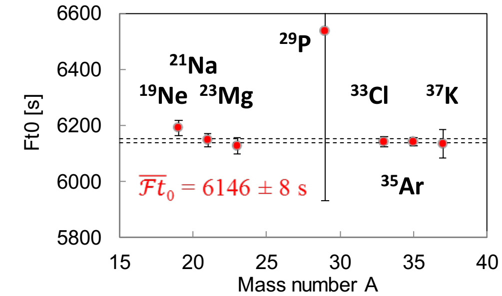


CENBG, LMU, IPNO, IFIC, LPSC, GANIL

DESIR: Fundamental interactions

Mirror transitions: T_z = -1/2 nuclei

$$\mathcal{F}t^{mirror}\left(1+\frac{f_A}{f_V}\rho^2\right) = 2\mathcal{F}t^{0^+\to 0^+} = \frac{K}{G_F^2 V_{ud}^2 (1+\Delta_R^V)}$$



-> V_{ud} = 0.97409 (66)

Q_β, T1/2, BR

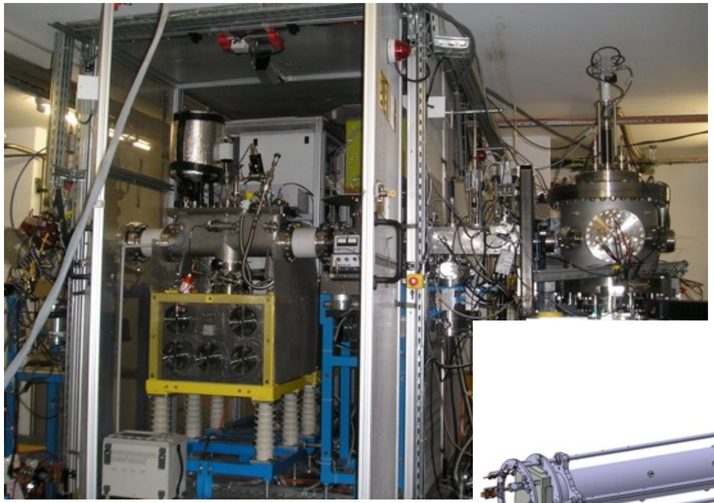
$\rho^2 = (1-a_{\beta\nu})/(a_{\beta\nu}+1/3)$

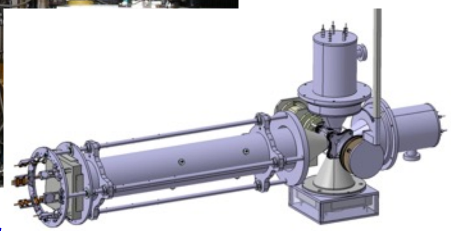
Independent tests of CKM unitarity

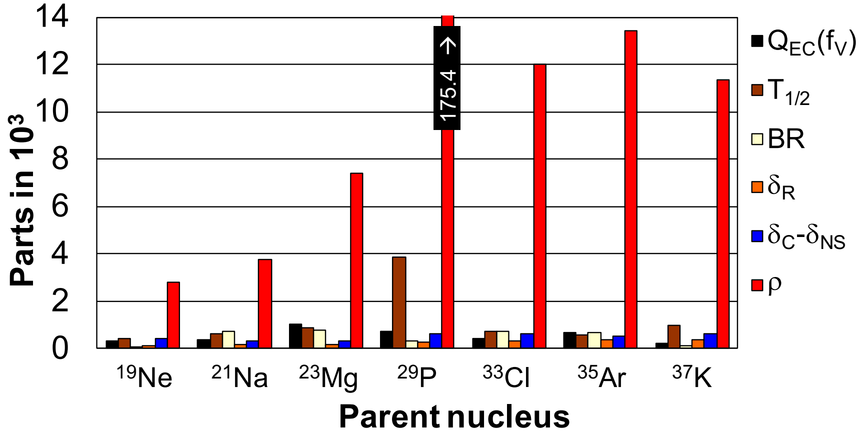
GT/F ratio from β–ν angular correlation measurements: LPCTrap

- **Complementary evaluation of $|V_{ud}|$**

-> SPIRAL1 beams: ^{21}Na, ^{23}Mg, ^{33}Cl, ^{35}Ar, ^{37}K, ^{39}Ca, ^{41}Sc







LPCC, IKS, CENBG, GANIL

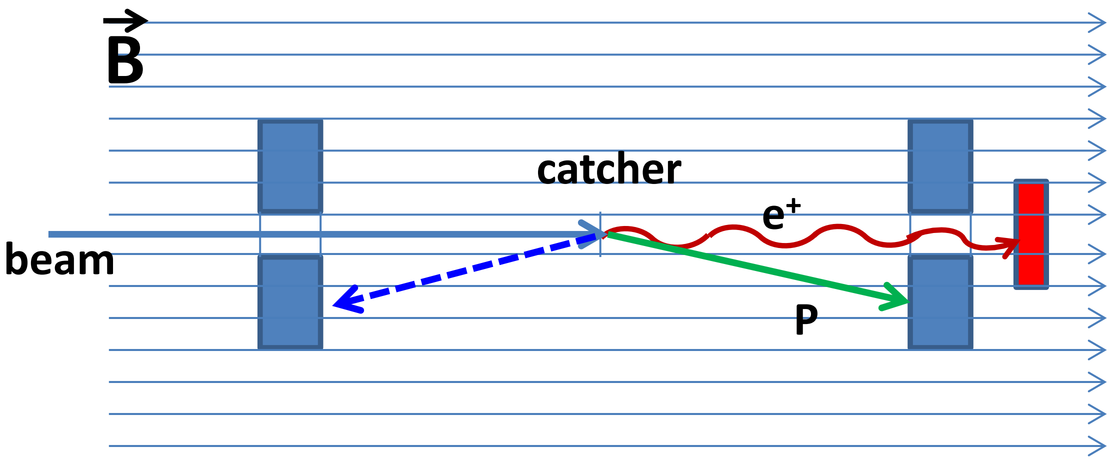
DETRAP

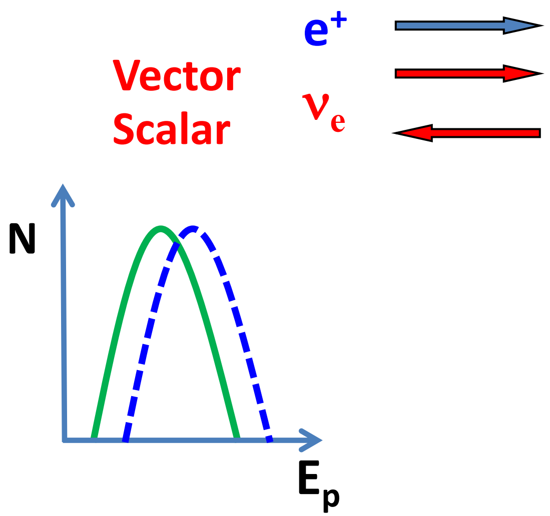
β–ν correlation coefficient measurements

$$dW \sim 1 + a\frac{\vec{p}_e\cdot\vec{p}_\nu}{E_e E_\nu} + b\Gamma\frac{m}{E_e} + \frac{\vec{I}}{I}\cdot\left[A_\beta\frac{\vec{p}_e}{E_e} + B_\nu\frac{\vec{p}_\nu}{E_\nu} + D\frac{\vec{p}_e\times\vec{p}_\nu}{E_e E_\nu}\right]$$

- **Limit on scalar currents:** from $a_{\beta\nu}$ in the Fermi β-p decay of ^{20}Mg, ^{24}Si, ^{28}S, ^{32}Ar, ^{36}Ca
  - ✓ $a_{\beta\nu}$ from the E_p energy shift associated with the recoil of the daughter ion
  - ✓ goal: $\Delta a_{\beta\nu}$ ~0.1%

WIZARD project, B. Blank et al.





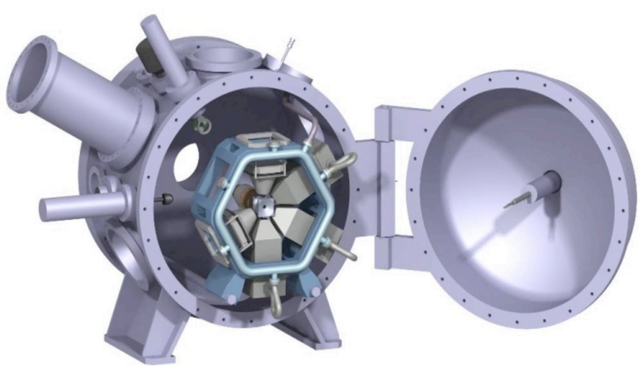
-> Proof of principle at ISOLDE with ^{32}Ar: ongoing adaptation of the WITCH spectrometer

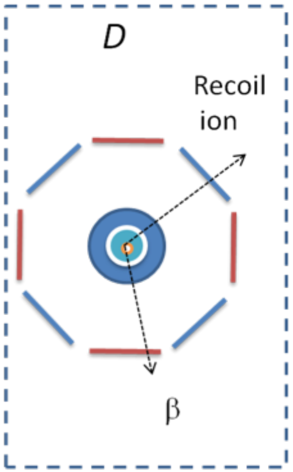
CENBG, IKS, LPCC, Rez

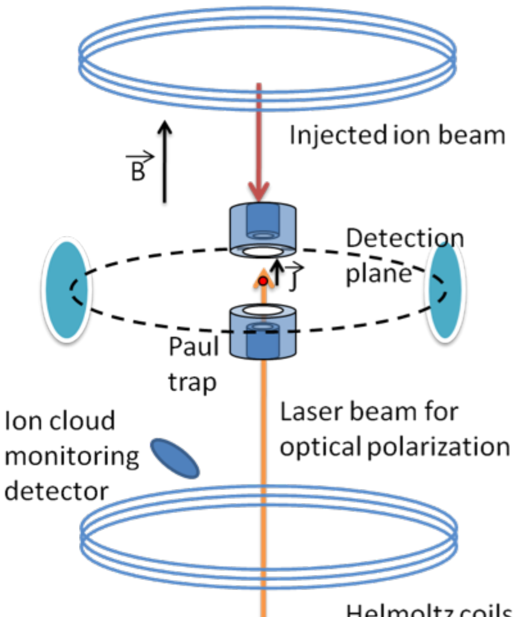
Correlation coefficient measurements with (laser-) polarized beams

$$dW \sim 1 + a\frac{\vec{p}_e\cdot\vec{p}_\nu}{E_eE_\nu} + b\Gamma\frac{m}{E_e} + \frac{\vec{I}}{I}\cdot\left[A_\beta\frac{\vec{p}_e}{E_e} + B_\nu\frac{\vec{p}_\nu}{E_\nu} + D\frac{\vec{p}_e\times\vec{p}_\nu}{E_eE_\nu}\right]$$

- A_β: deviation from “maximal parity violation” in β decay: ^{21}Na , ^{32}P, ^{35}Ar
  -> right-handed currents
- D correlation: ^{19}Ne , ^{23}Mg, ^{39}Ca with an upgraded LPCTrap
  -> CP violation -> T-reversal invariance
  ✓ goal: $D < 10^{-4}$



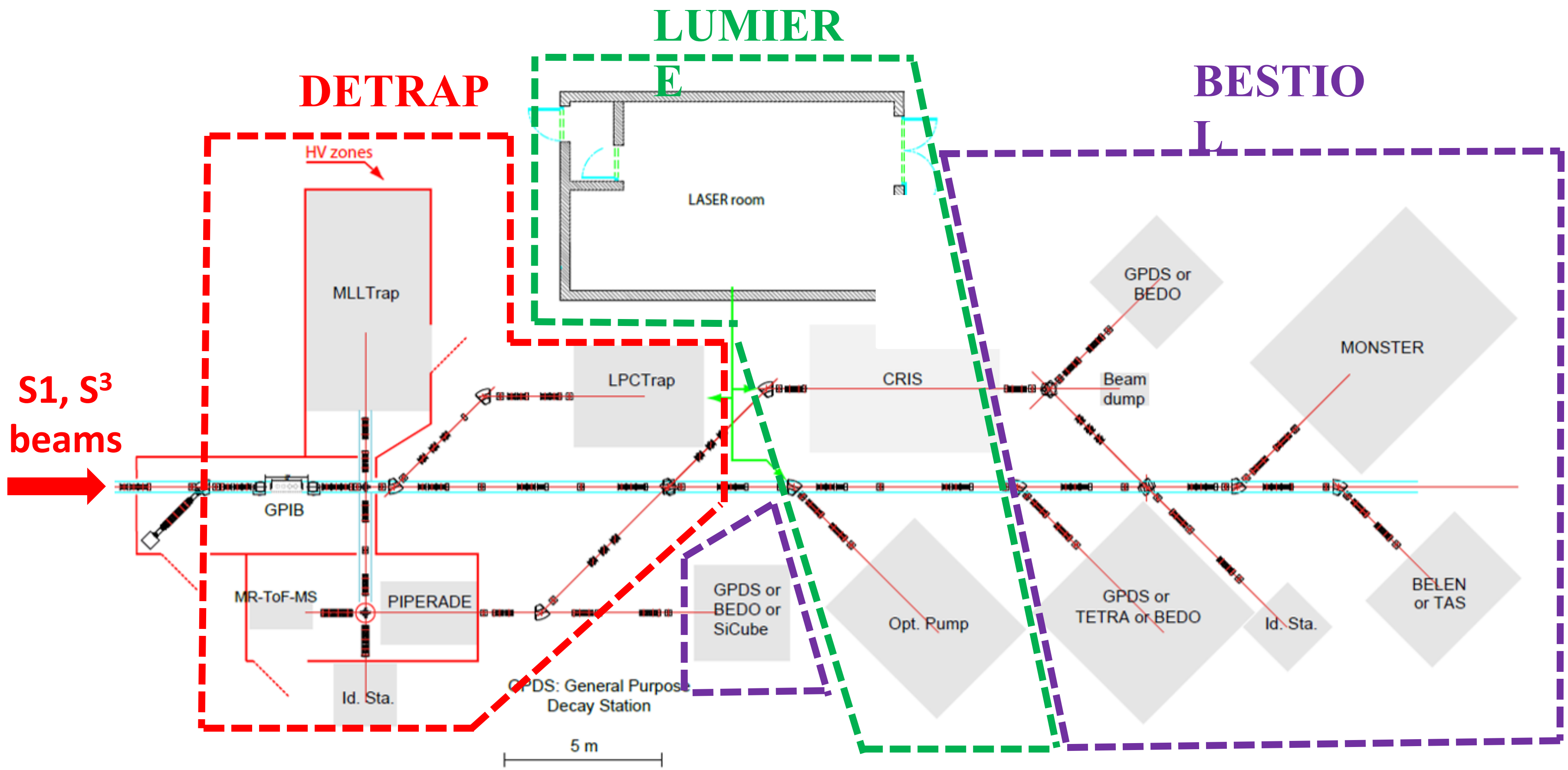




-> Proof of principle at JYFL with ^{23}Mg: ongoing work, Winningmotions, *P. Delahaye et al.*
GANIL, LPCC, IPNL, JYFL, IKS, ISOLDE, Univ. Manchester

DESIR: Experimental equipment

-> 3 connected and complementary groups: DETRAP, LUMIERE, BESTIOL



DESIR: Timeline & Physics program Conclusions

- **Status of the project**
  - ✓ Funding secured
  - ✓ Building construction to start in 2020 --- Hopefully!
  - ✓ Installation of the experimental equipment in 2022
  - ✓ Day-1 experiments with RIBs: 2023 at best

- **Physics program**
  - ✓ Ground and isomeric states (decay) properties
  - ✓ Nuclear structure studies

  } Complementary to S^3 -LEB: expected higher $M/\Delta M$ and laser spectroscopy resolution

  - ✓ Fundamental interactions studies

  - ✓ With n-deficient beams from SPIRAL1 and S^3
  - ✓ Sample purification and polarization

-> Scientific and technical synergies with S^3-LEB
-> A fast(er) gas cell would allow to study shorter lived nuclei