# HIE-ISOLDE

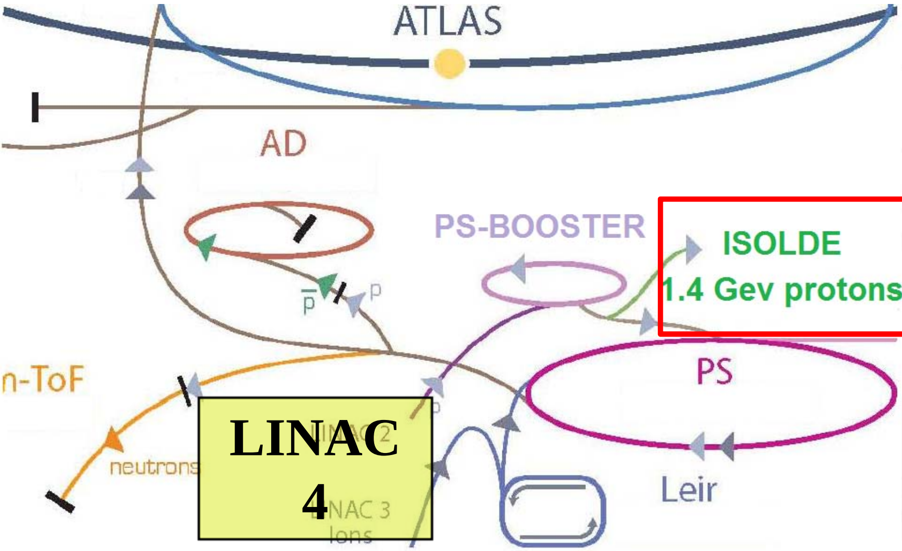
# CERN-ISOLDE towards the future!

Mats Lindroos

Acknowledgements to all in the HIE-ISOLDE family

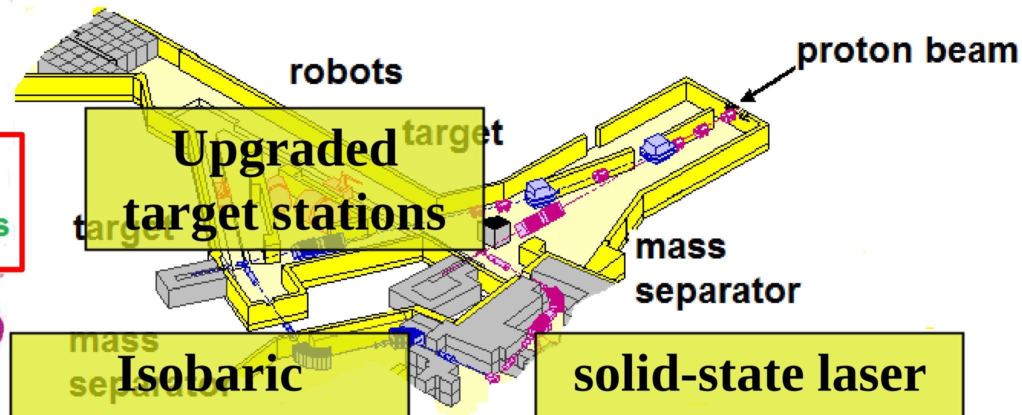
# ISOL method of radioactive ion beam production

**DRIVER ACCELERATOR**




**LINAC 4**

**PRIMARY TARGET**




**Upgraded target stations**

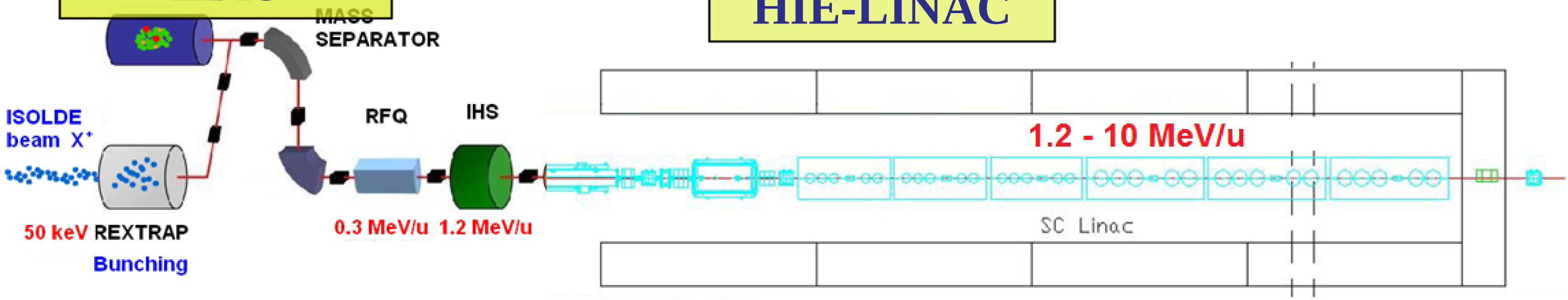
**Isobaric mass separator**

**solid-state laser for ionisation**

**High intensity EBIS**

**POST-ACCELERATOR**

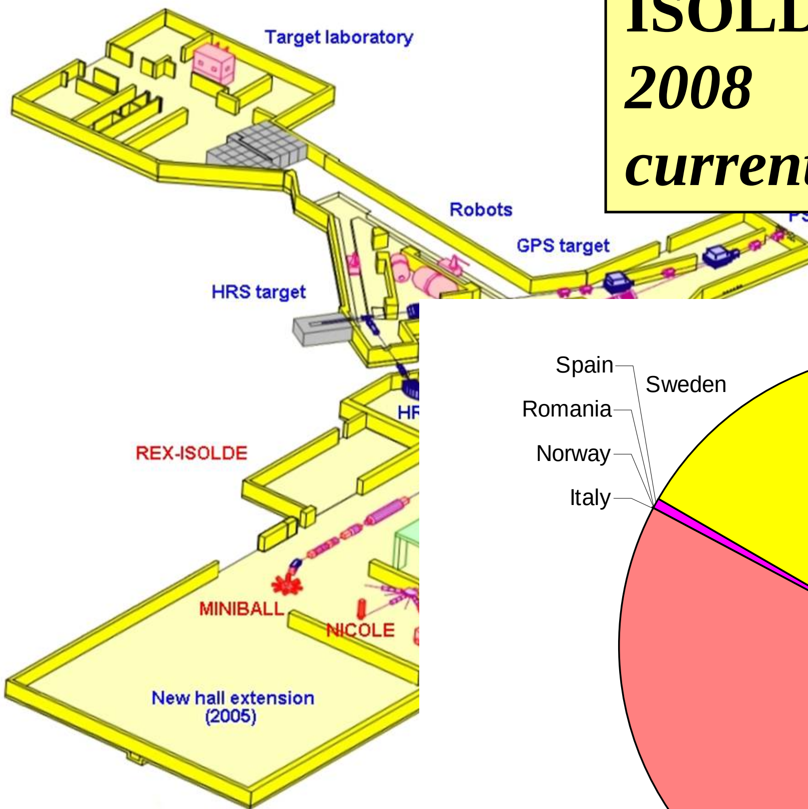
**HIE-LINAC**

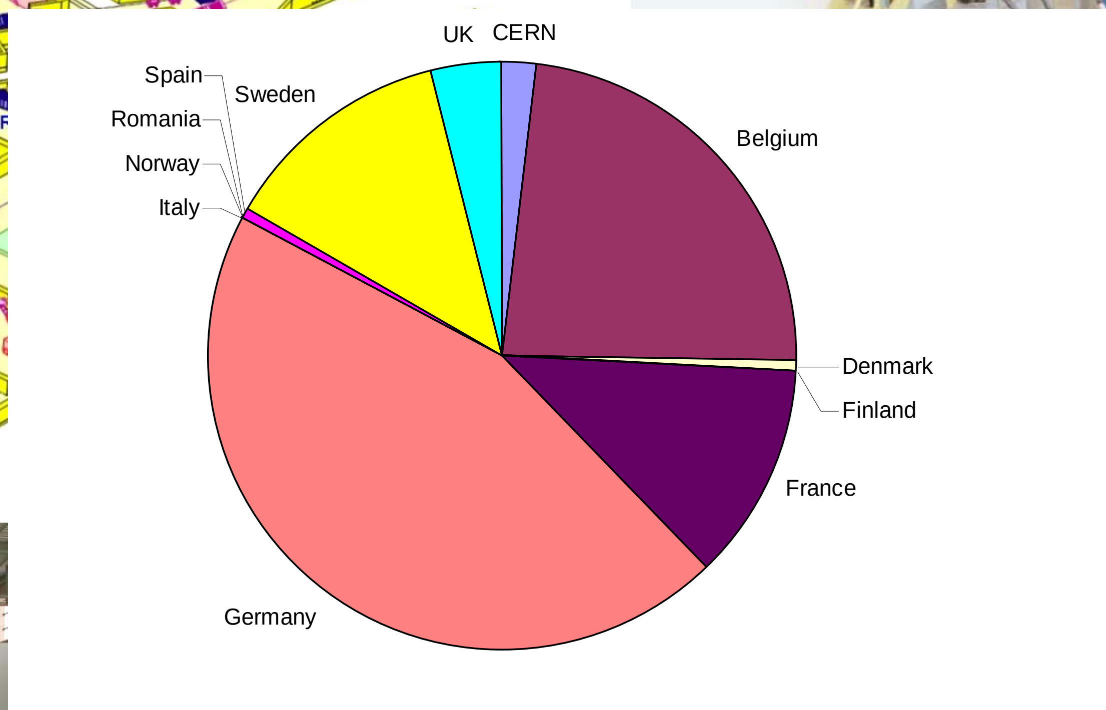


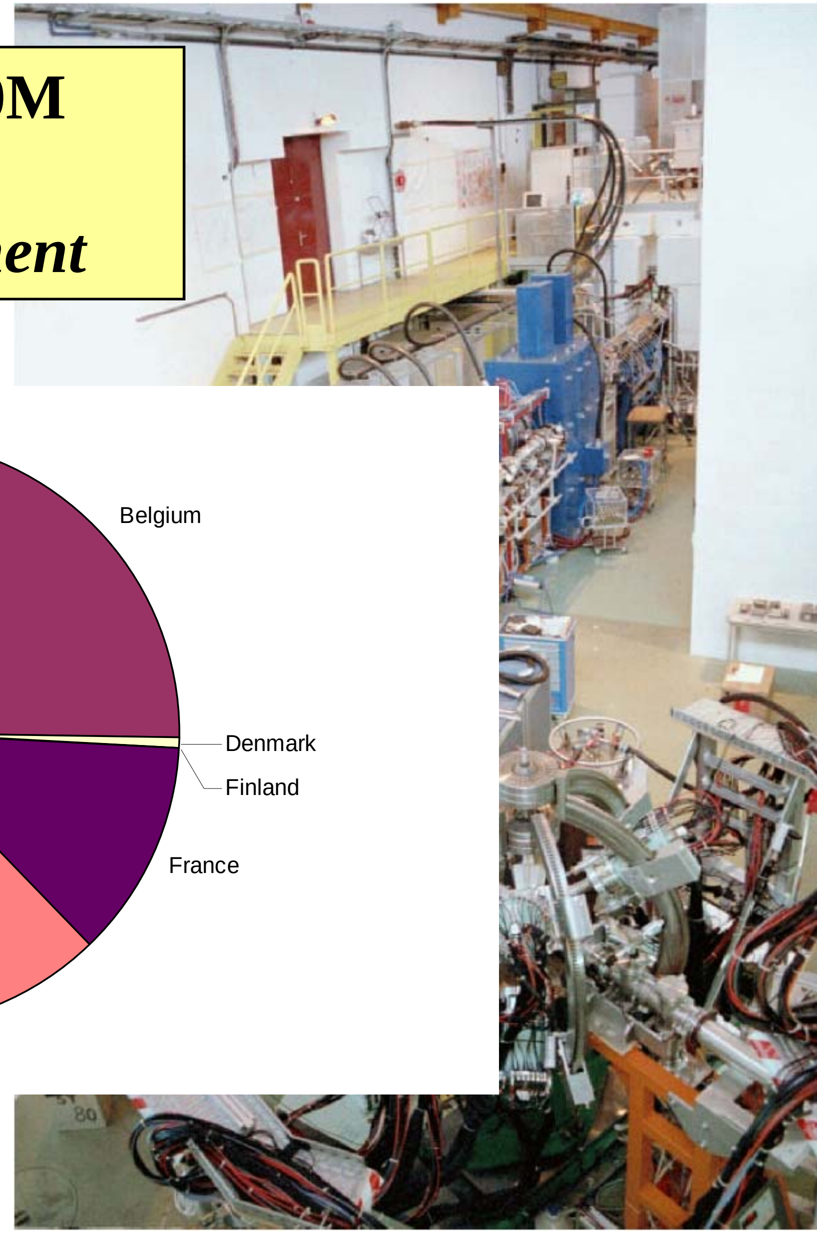

**HIE-ISOLDE upgrades**

**P. Butler**

# ISOLDE: ~£20M
## *2008*
## *current equipment*



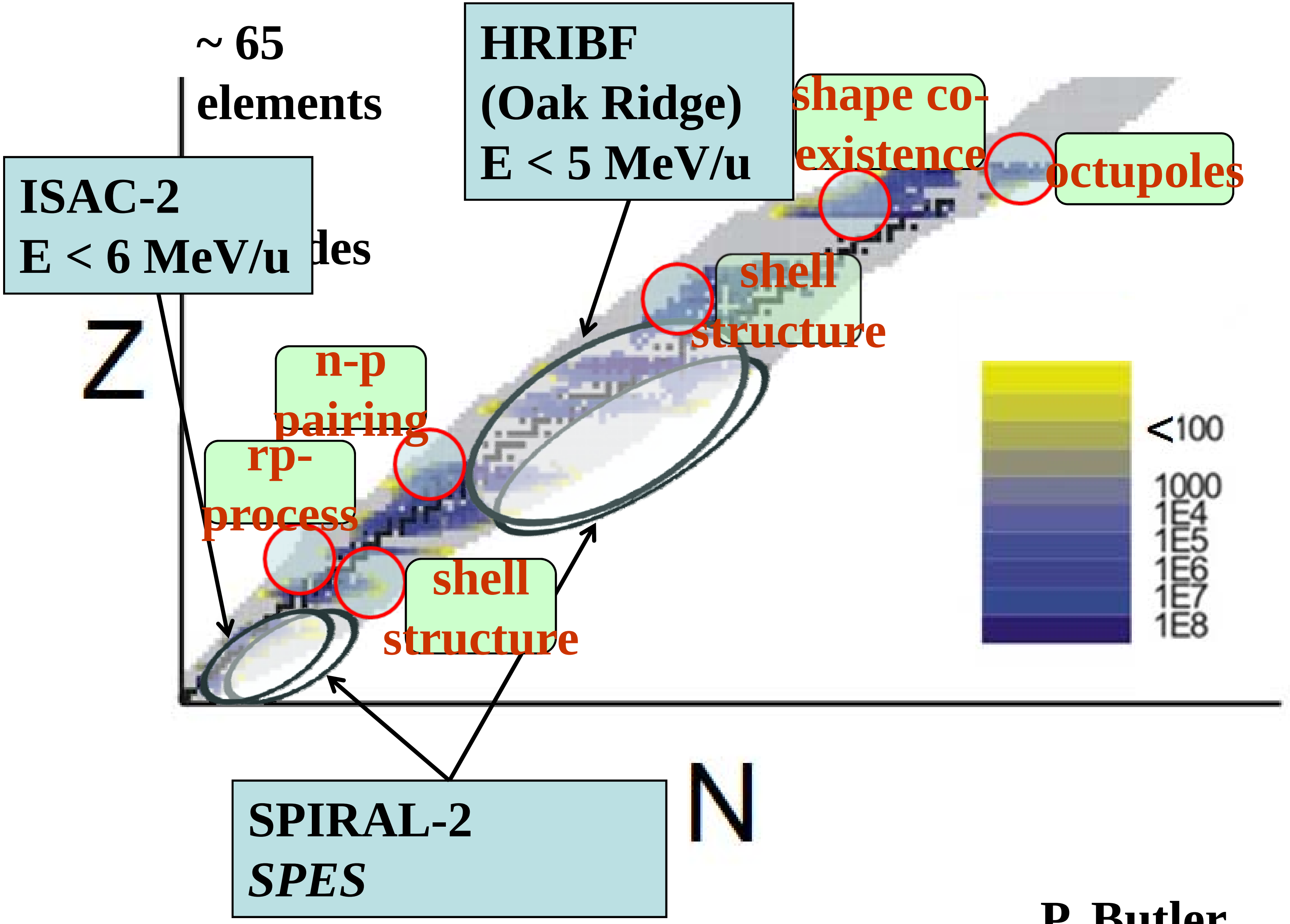



**P. Butler**

# HIE-ISOLDE: Next step with three objectives

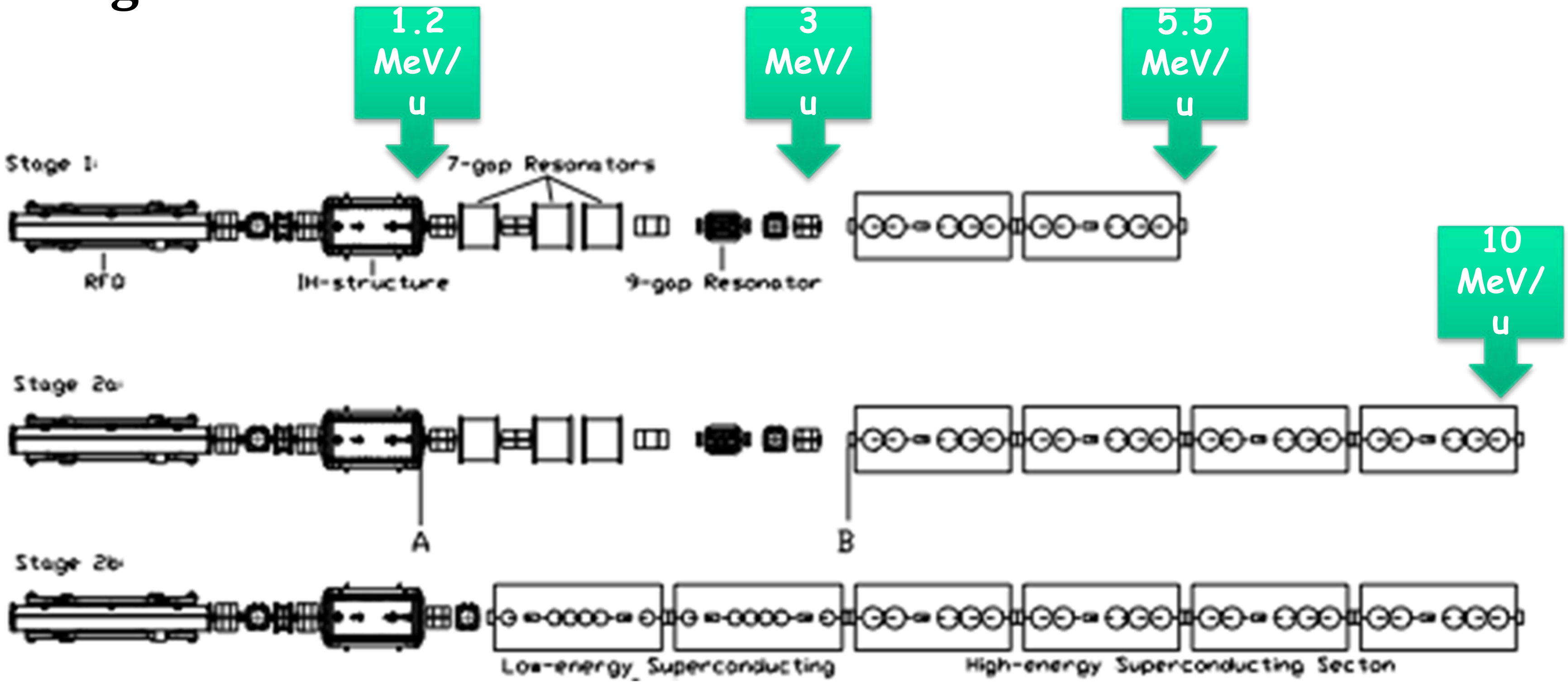
- ✓ REX energy upgrade and increase of current capacity (Matteo Pasini)
  - Energy upgrade in 3 stages: 5.5 MeV and 10 MeV/u and lower energy capacity
- ✓ ISOLDE proton driver beam intensity upgrade - strongly linked to PS Booster improvements including linac4 (Richard Catherall)
  - Faster cycling of the booster
  - New target stations for ISOLDE
  - New targets
  - New target handling system
- ✓ ISOLDE radioactive ion beam quality – more than half already financed through the ISOLDE collaboration
  - Smaller longitudinal and transverse emittance
    - Done – RFQ cooler operational
  - RILIS upgrade and LARIS construction
    - Done
  - Charge breeder upgrade
  - Better mass resolution
  - Continue target and ion source developments

# Yields from HIE-LINAC

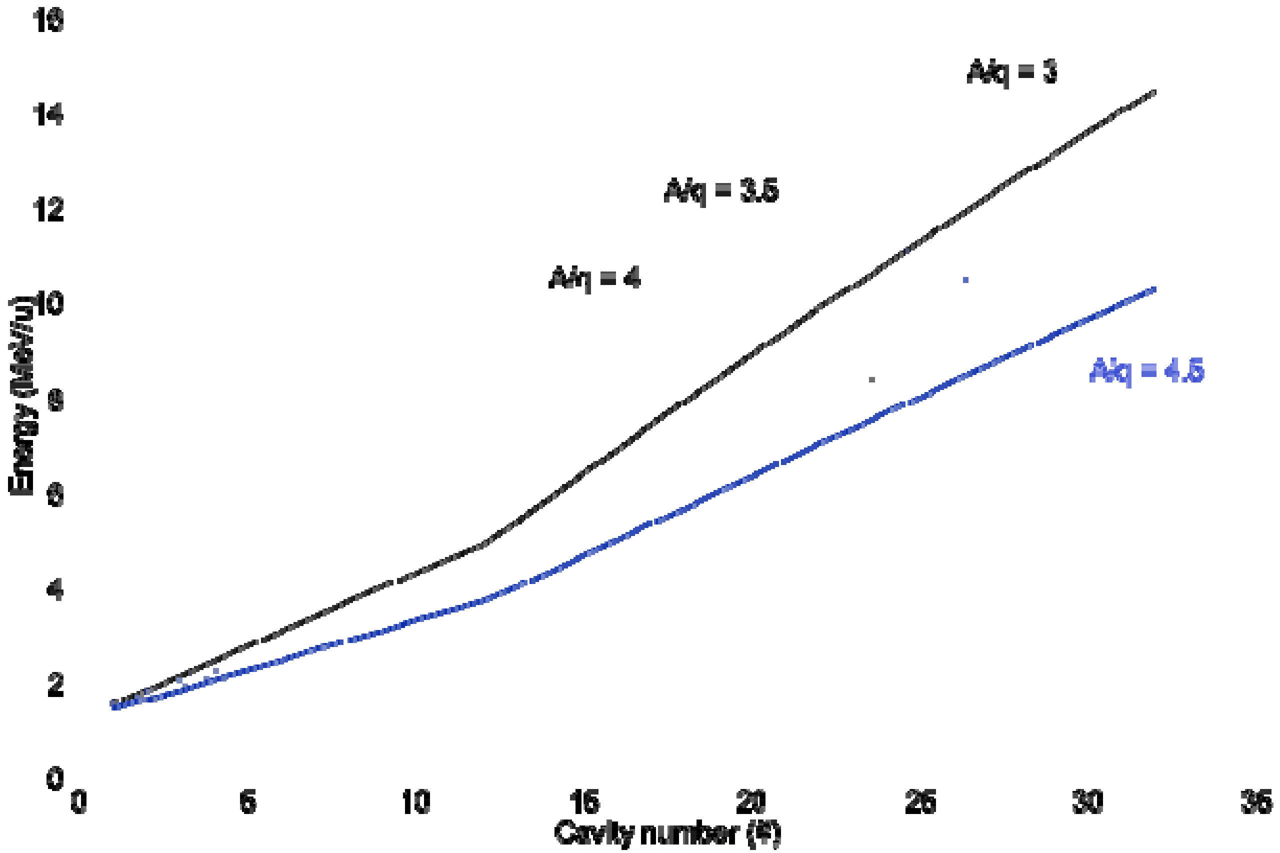



P. Butler

# 3 stages installation



# LINAC energy variability



# 101.28 MHz Nb sputtered QW cavities

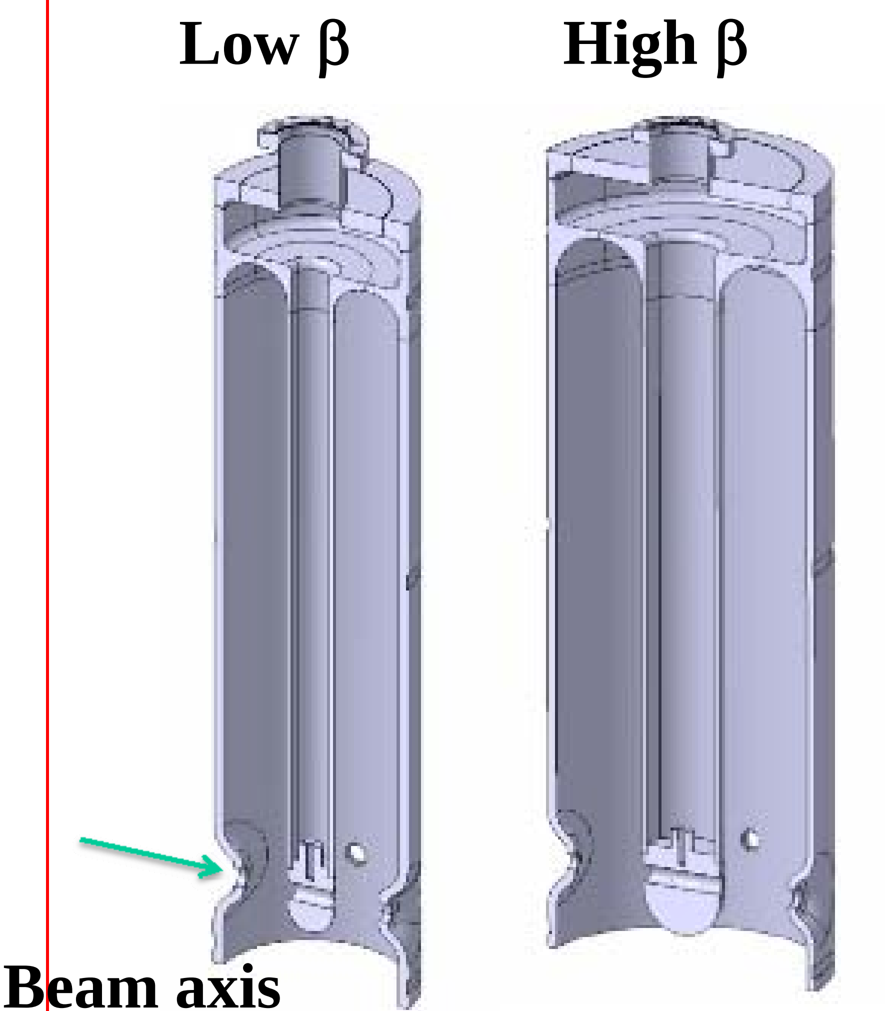


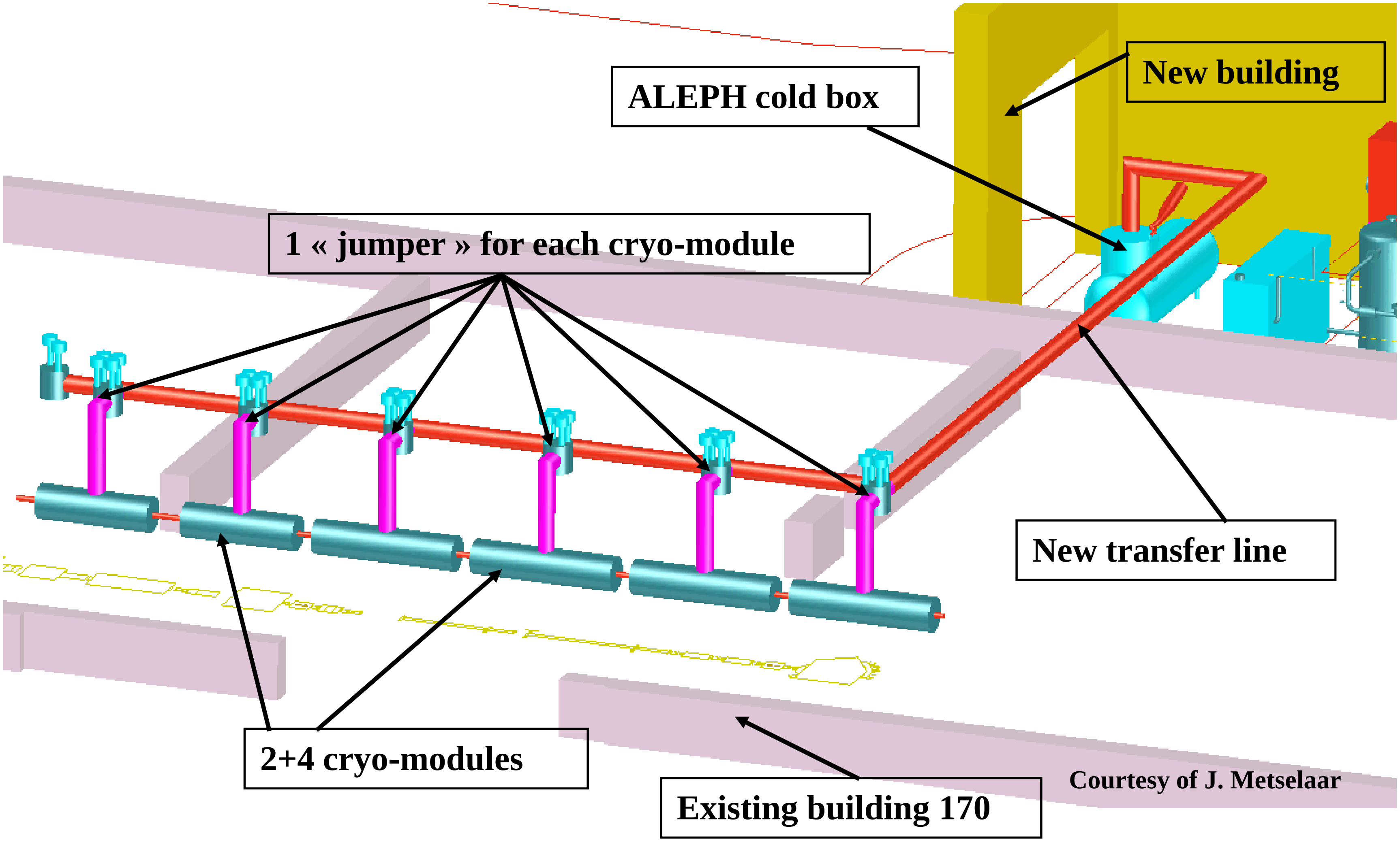

Table 1: Cavity design parameters

| Cavity | Low $\beta$ | high $\beta$ |
|---|---|---|
| No. of Cells | 2 | 2 |
| f (MHz) | 101.28 | 101.28 |
| $\beta_0$ (%) | 6.3 | 10.3 |
| Design gradient $E_{acc}$(MV/m) | 6 | 6 |
| Active length (mm) | 195 | 300 |
| Inner conductor diameter (mm) | 50 | 90 |
| Mechanical length (mm) | 215 | 320 |
| Gap length (mm) | 50 | 85 |
| Beam aperture diameter (mm) | 20 | 20 |
| $U/E_{acc}^2$ (mJ/(MV/m)$^2$ | 73 | 207 |
| $E_{pk}/E_{acc}$ | 5.4 | 5.6 |
| $H_{pk}/E_{acc}$ (Oe/MV/m) | 80 | 100.7 |
| $R_{sh}/Q$ ($\Omega$) | 564 | 548 |
| $\Gamma = R_s \cdot Q_0$ ($\Omega$) | 23 | 30.6 |
| $Q_0$ for 6MV/m at 7W | $3.2 \cdot 10^8$ | $5 \cdot 10^8$ |
| TTF max | 0.85 | 0.9 |
| No. of cavities | 12 | 20 |

# Nb sputtering cavity development

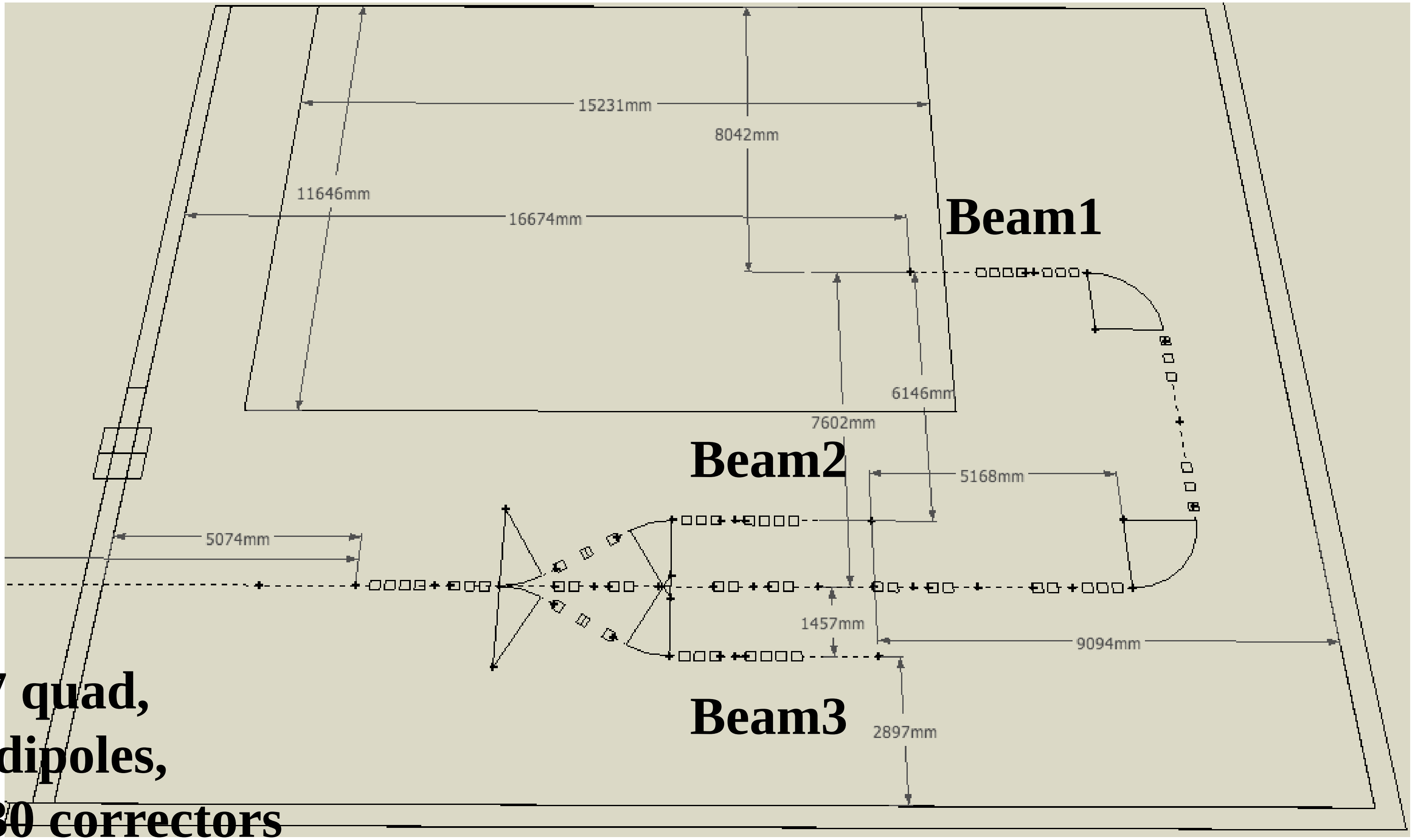
- High $\beta$ cavity prototype in fabrication
- Sputtering chamber design complete and in fabrication
- Chemical treatment facility refurbished and ready for tests with dummy cavity
- Clean room refurbished (there was a problem with floor tiles)
- Tools for handling and manufacturing in fabrication

# Cryogenics



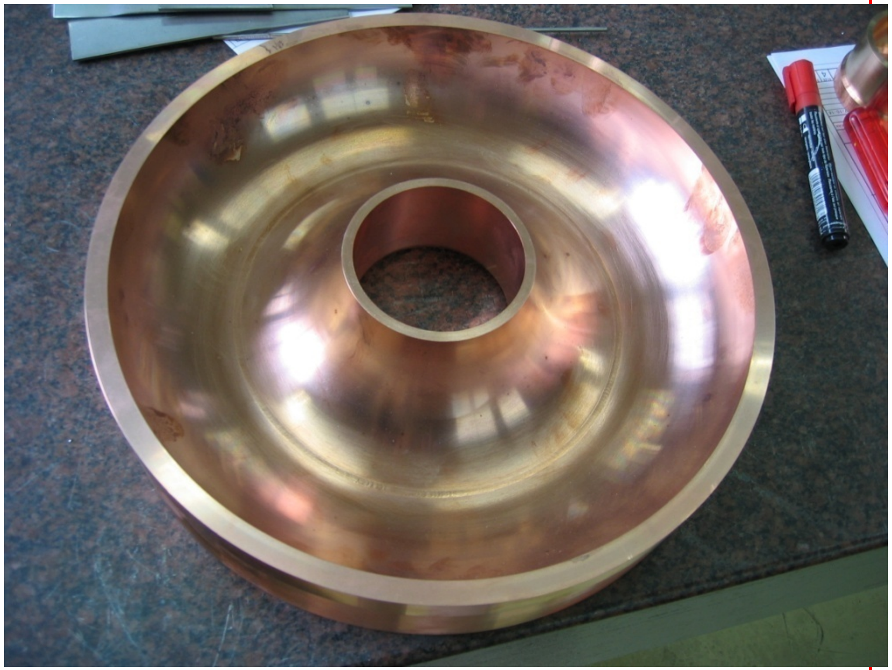
New building
ALEPH cold box
1 « jumper » for each cryo-module
New transfer line
2+4 cryo-modules
Existing building 170
Courtesy of J. Metselaar

# Option 2




**57 quad,**
**5 dipoles,**
**~30 correctors magnets**

# Welding test: 1000 mm distance e-beam



**Roughness test performed after SUBU chemical polishing, 20 µ**
**Achieved Ra ≤ 0.8 µm, target value**

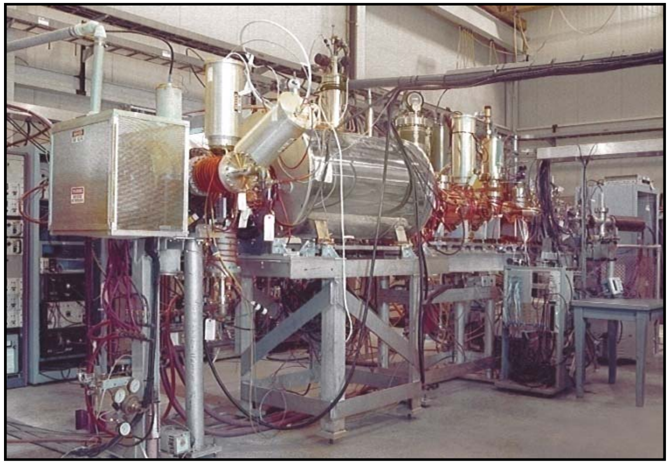
# Manufacturing of beam ports: flat test

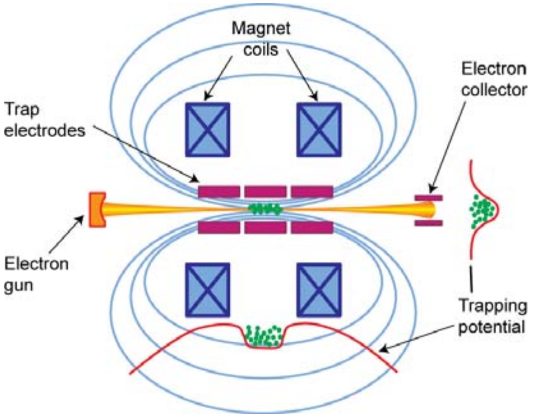
Starting thickness 10 mm
Residual thickness > 8 mm

# Bias electrode by water jet cutting

# REX space charge limits – REX trap and chargebreeder

- The low energy stage at REX can today not handle the full intensity of some ISOLDE beams:
  - A new EBIS with higher fields and higher electron currents
  - A RFQ cooler for operation in continuous injection mode (ACCU mode) with the EBIS
  - Proposal submitted to the DOE in collaboration with MSU, TRIUMF, LLNL, MPI-K and ORNL





# DOE proposal - Comparison EBIS/ECR/1+

| | | Proposed high-intensity EBIS/T breeder | Next-generation ECR breeder | 1+ scheme with stripping | Gain EBIS/T vs ECR | Gain EBIS/T vs 1+ |
|---|---|---|---|---|---|---|
| **Efficiency for single charge-state re-acceleration** | ε (A<40) | > 60 % | < 20 % | <40% | >3 | >1.5 |
| | ε (A=100) | > 50 % | < 20 % | <10% | >2.5 | >5 |
| | ε (A=200) | > 40 % | < 20 % | <5% | >2 | >8 |
| Chance of reaching breeding performance | | Present performance 25-50% of values | Present performance 20-40% of values | NA | | |
| **Breeding (trapping) time** | | <20 ms | >100 ms | NA | >5 | NA |
| **Beam rate limit** | | $>10^{11}$/s | $>>10^{11}$/s | no limit | | |
| Chance of reaching beam rate capability | | RHIC test EBIS: $>10^9$ ions/pulse | No risk | No risk | | |
| **Beam purity - stable beam current intensities** | | pA | >> μA | NA | >>1000 | NA |

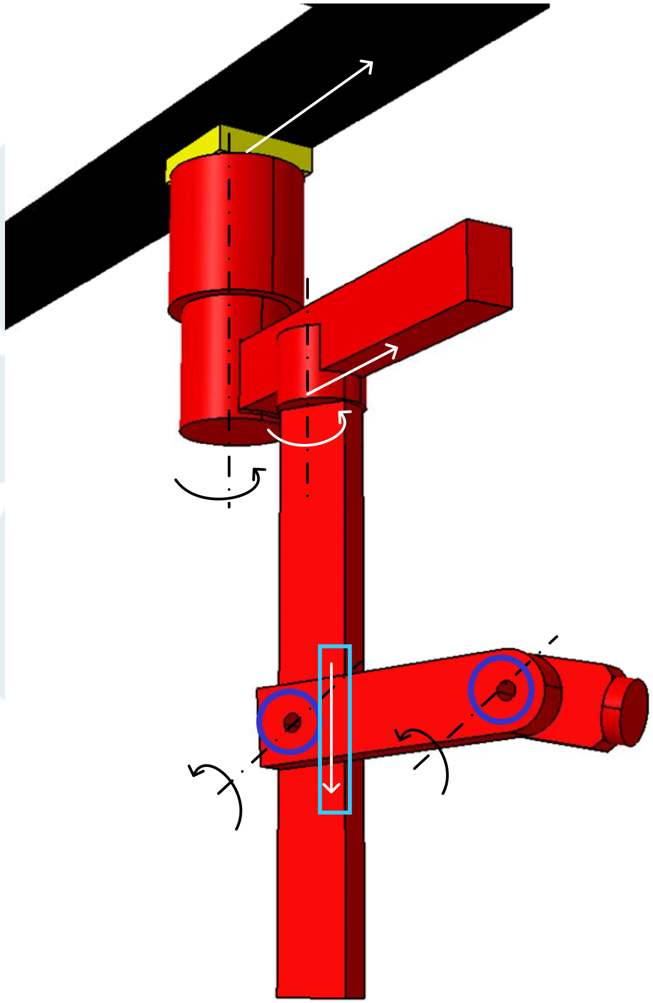
| | Proposed High-Intensity EBIT | MSU EBIT | TITAN EBIT | BNL test EBIS | REX-EBIS |
|---|---|---|---|---|---|
| Electron beam energy (keV) | < 60 | < 30 | < 60 | <30 | < 6 |
| Electron beam current (A) | < 10 | < 5 | <5 | <20 | < 0.5 |
| Central current density (A/cm²) | $<10^5$ | $<10^4$ | $<10^4$ | <600 | <200 |
| Magnet design | Helmholtz Coil + Solenoid | Helmholtz Coil + Solenoid | Helmholtz Coil | Solenoid | Solenoid |
| Maximum magnetic field (T) | 9 | 6 | 6 | 5 | 2 |
| Trap length (m) | 1 m | 0.5 m | 0.1 m | 0.7 m | 0.8 m |

**O. Kester et al.**

# Higher driver beam intensities

- Cost for the faster cycling of the booster included in this proposal
  - Linac 4 will have major impact on the ISOLDE "targetry" and the project includes necessary modifications for linac 4 (but not the cost of linac 4!)
- Target handling, targets, waste handling and general safety in target area
  - Major improvement of working conditions for radiation workers compared to present situation and fully in line with European legislation

# Manipulator concept design



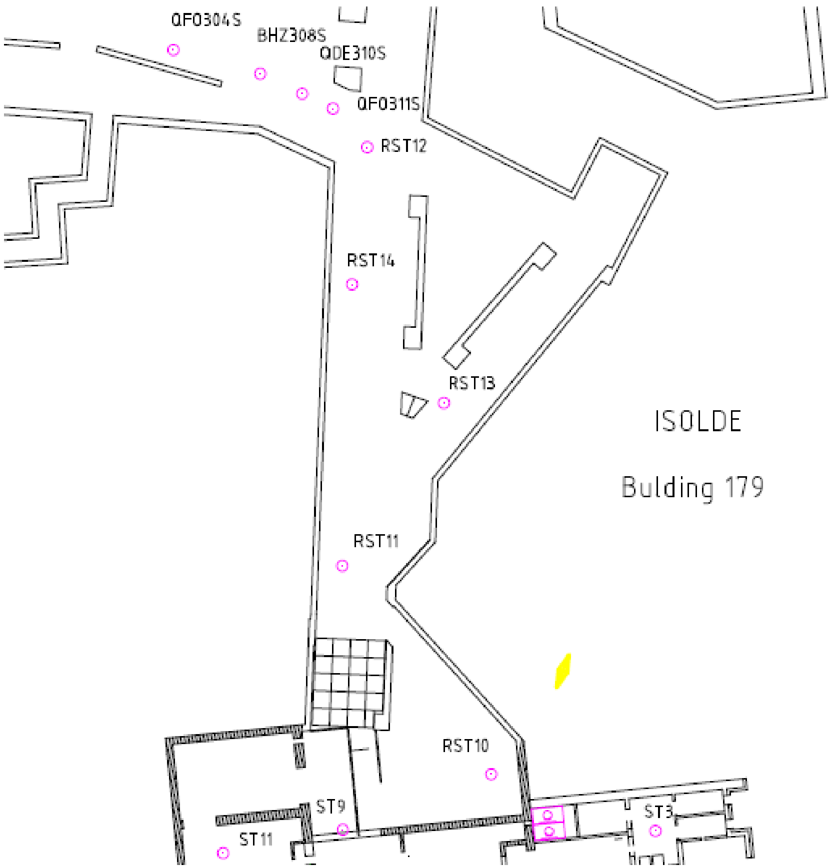
- **6-DOF Manipulator mounted on ceiling monorails**
- **Equipped with tool changer for mounting different tools**
- **Recoverable by decoupling (remotely) rail gear drive**
- **High lifting capacity (FFE)**
- **Target & electrode accurate / sensitive operations**

- **Options:**
  - Teleoperation with force reflection into Master
  - ...

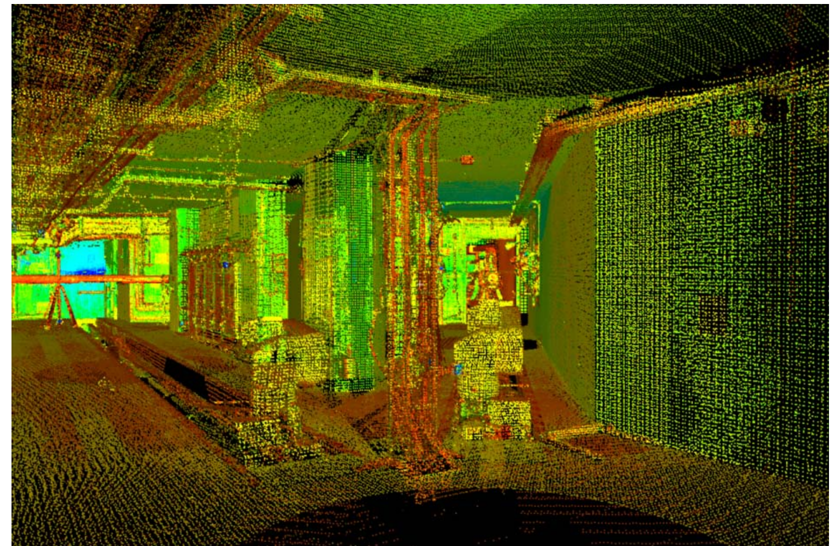


TAMPERE UNIVERSITY OI
IHA - Department of Intelligent

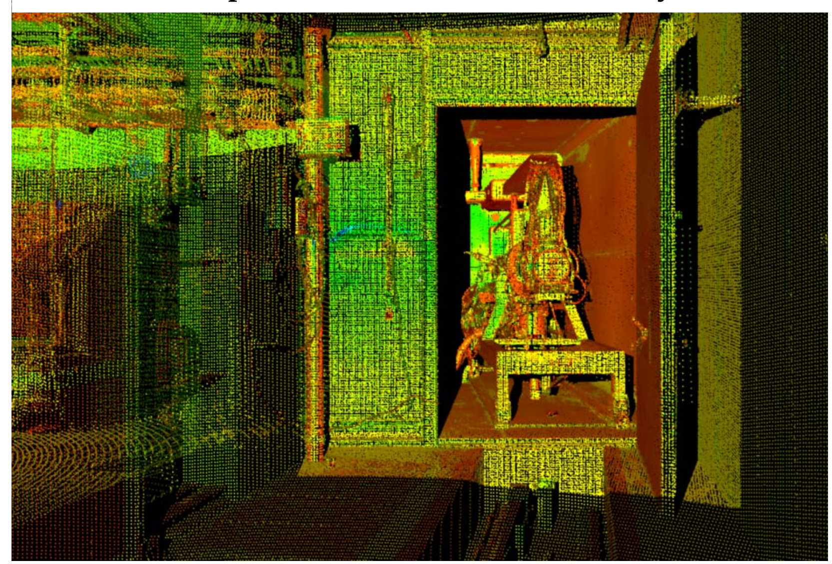
# 1.5 - The 3D  Laser Scan




**Reference Points**



**Cloud of point in the CERN coordinate system**

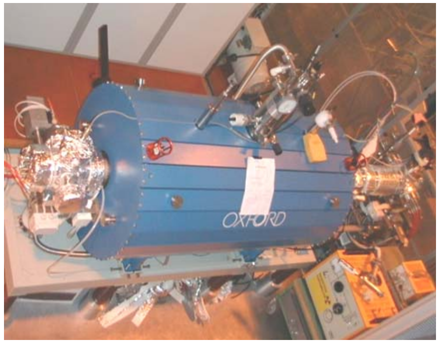


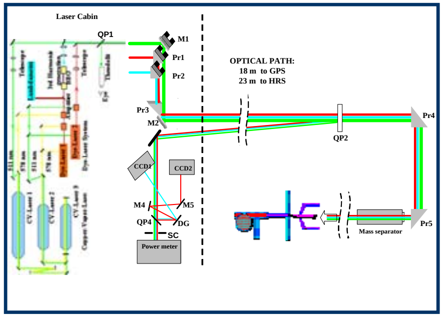


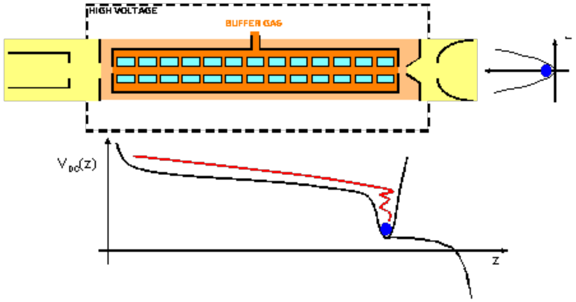
J. Sarret, L. Bruno

# Beam quality

- Beam manipulation with traps and ionization with lasers permits tailoring of RI beams for Users
- Essential to strengthen target R&D to keep ISOLDE as a world leading ISOL lab.
- Major contribution received from UK and Sweden for RILIS and RFQ cooler (2655 kCHF)

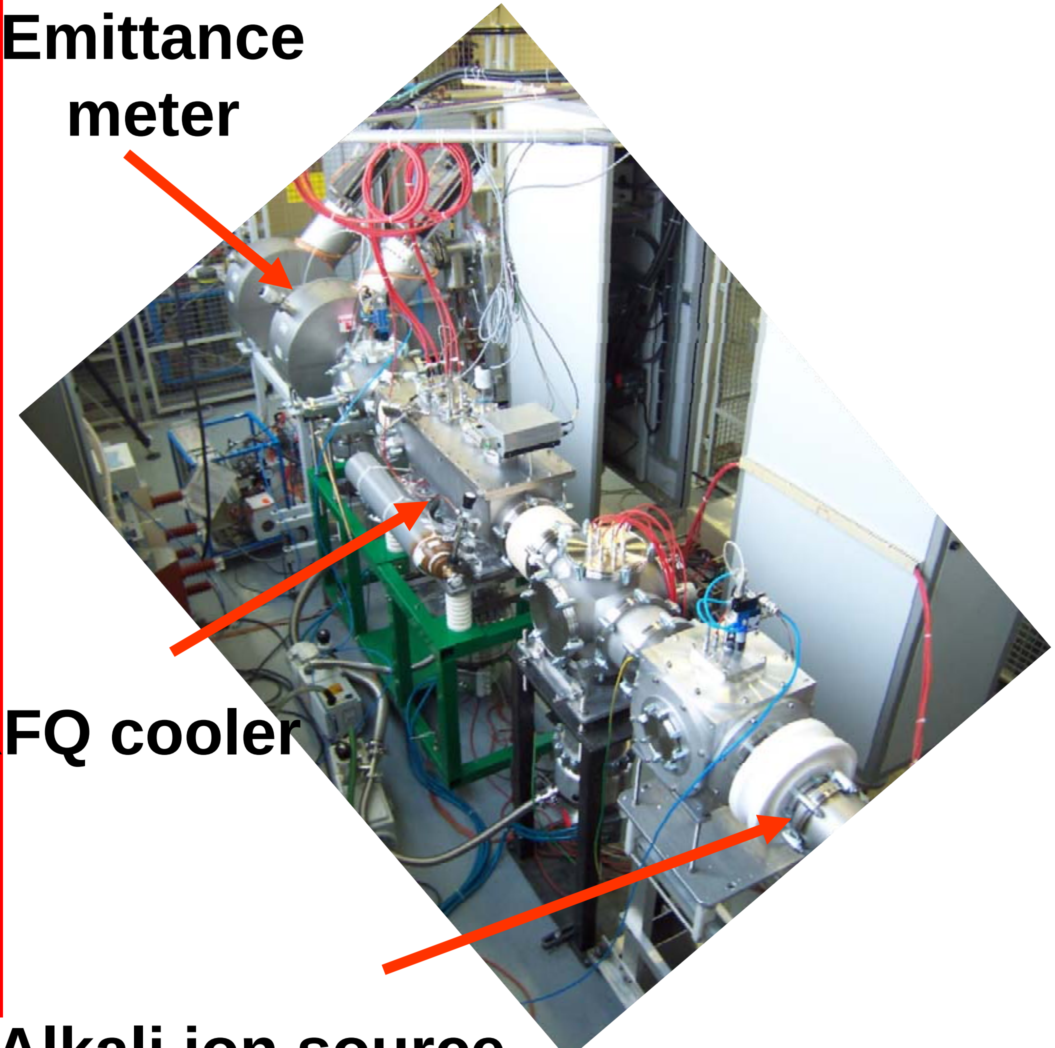


# RFQ cooler "ISCOOL"
EPSCR grant (Manchester, Birmingham)

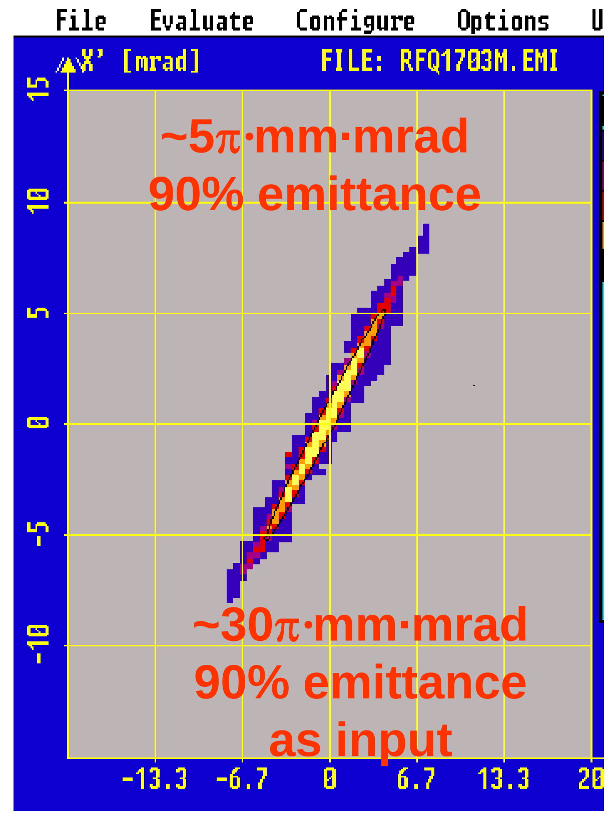
**Emittance meter**

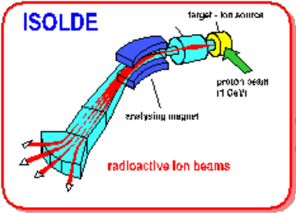


**RFQ cooler**

**Alkali ion source**

## Continuous mode



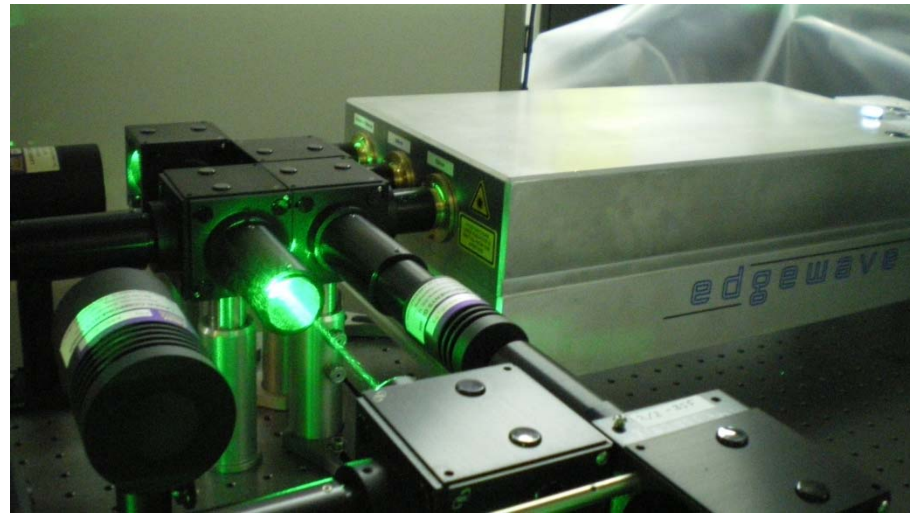



# d:YAG lasers installed at RILIS

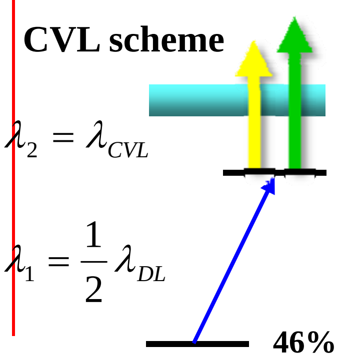
**Diode Pumped Solid State Nd:YAG Lasers as replacement of Copper Vapor Lasers:**

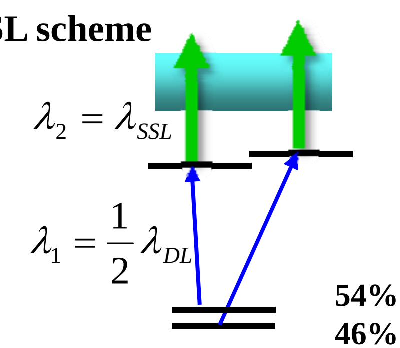
**CVL** → **SSL**

| CVL | SSL |
|---|---|
| 15 ns @ 11 kHz | 8 ns @ 10 kHz |
| Green Beams 45 W @ 511 nm | Green Beams 80 - 100 W @ 532 nm |
| Yellow Beams 35 W @ 578 nm | UV Beam 18 W @ 355 nm |
| | IR Beam 35 W @ 1064 nm |




**Ion beam produced with the SSL in 2008:** **Ga, Tl, Be, Nd, Cu, Mg, *Pb***




**Improvement of Ga ionization efficiency by SSL :**

- Two dye lasers were applied at 1st step of excitation - x 2
- More power could be delivered to HRS target at the 2nd step of excitation
- Better power stability

# HIE-ISOLDE external contribution: Where are we?

- External grant from Belgium
- Second grant from Belgium approved for both physics programme and SC linac construction for HIE-ISOLDE
- Proposal submitted in the UK for HIE-linac
- Approved WP in EUCARD for R&D on thin film techniques
- RFQ cooler WP and RILIS WP financed and (almost) completed
- Proposal being prepared in the US to DOE for joint development of new high-intensity EBIS
- Discussions with CERN Mgt on CERN contribution.

# Total all parts of project

| | | Swiss Francs | | | |
|---|---|---|---|---|---|
| | | Still required | | Received | |
| | | Staff | Material | Staff | Material |
| | | FTE | kCHF | FTE | kCHF |
| **1a *** | **LINAC prototyping and cryo design** | **0.0** | **425** | **5.5** | |
| **1b *** | **LINAC 3.0 - 5.5 MeV/u** | **25.5** | **2,416** | | **4,472** |
| 1c | Linac 5.5 - 10 MeV/u | 19.0 | 3,350 | | |
| 1d | LINAC lower energies | 9.5 | 1,325 | | |
| **1e *** | **Beam lines for experimental area** | **1.0** | **0** | | **500** |
| 2 | REX trap and charge breeder | 12.1 | 2,238 | | |
| **3 *** | **TS consolidation** | | **2,000** | | |
| | REX UPGRADE | 67.1 | 11,754 | 5.5 | 4,972 |
| 4 | Targets & Front-ends | 25.8 | 8,040 | | 60 |
| 5 | PSB 900 ms | 9.0 | 2,000 | | |
| | PROTON DRIVER BEAM | 34.8 | 10,040 | 0.0 | 60 |
| **6 *** | **RFQ cooler** | **0.0** | **0** | | **500** |
| **7 *** | **RILIS upgrade** | **0.0** | **0** | | **2,400** |
| 8 | High-charge state beams | 1.1 | 800 | | |
| 9 | New HRS | 0.8 | 1,100 | | |
| | BEAM QUALITY | 1.9 | 1,900 | 0.0 | 2,900 |
| **10 *** | **Radiation protection consolidation** | **1.0** | **750** | | |
| 11 | Vacuum consolidation | 8.5 | 2,408 | | |
| | CONSOLIDATION | 9.5 | 3,158 | 0.0 | 0 |
| | TOTAL | 113.3 | 26,852 | 5.5 | 7,932 |
| | Total Material | 34,784 | | | |
| | Total Personnel | 10,000 | | | |
| | **PHASE I** | **27.5** | **5,591** | **5.5** | **7,932** |
| | **Total Material Phase I** | **13,523** | | | |
| | **Total Personnel Phase I** | **2,778** | | | |

# Next steps

- The HIE-ISOLDE project
  - Presentation for Research Board in spring
  - Organization, responsibilities and structure fixed
- New grant proposals and in-kind contributions
  - HIE-linac
  - New EBIS construction, commissioning and installation
  - New High Resolution Mass separator
  - Study and engineering support for intensity upgrade

## Conclusions

- HIE-ISOLDE is the future for Radioactive beam physics at CERN
  - Participative project
  - Well defined sub-projects with scientific and R&D return for labs and research foundation in charge
- Radioactive beam physics is just in the beginning...
  - Future facilities such as EURISOL offers exciting research opportunities and interesting technical challenges