HIE-ISOLDE
The technical options

Mats Lindroos and Matteo Pasini, the ISOLDE technical team and the ISOLDE collaboration

(Yacine Kadi)

HIE-ISOLDE: Next step with three objectives

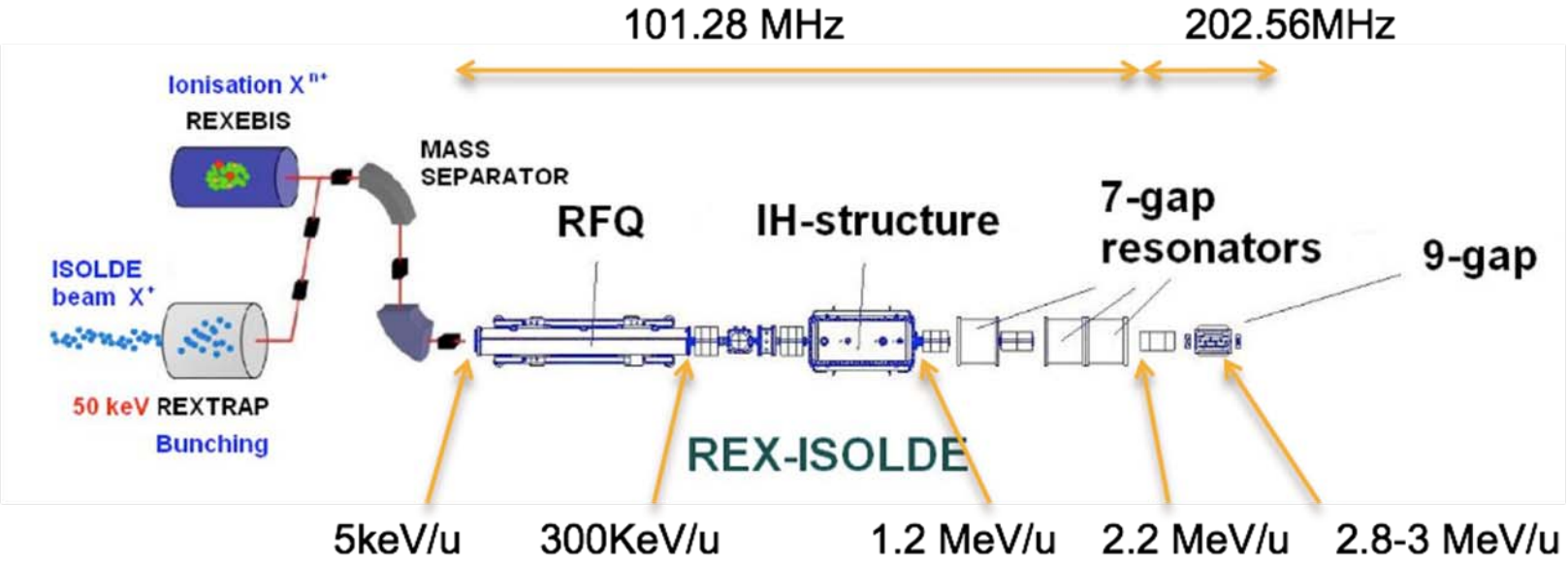
- ✓ ENERGY: REX energy upgrade and increase of current capacity (Matteo Pasini)
  - Energy upgrade in 3 stages: 8 MeV and 10 MeV/u and lower energy capacity

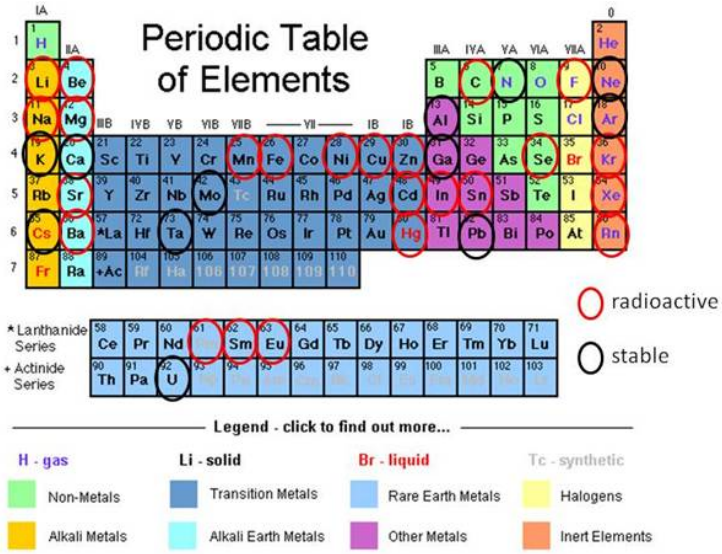
- ✓ QUALITY: ISOLDE radioactive ion beam quality – more than half already financed through the ISOLDE collaboration
  - Smaller longitudinal and transverse emittance
    - Done
  - RILIS upgrade and LARIS construction
    - Done
  - Charge breeder upgrade
  - Better mass resolution
  - Continued target and ion source developments
    - On-going and absolutely essential!

- ✓ INTENSITY: ISOLDE proton driver beam intensity upgrade - strongly linked to PS Booster improvements including linac4 (INTENSITY WP, Richard Catherall)
  - Faster cycling of the booster
  - New target stations for ISOLDE
  - New target design
  - New target handling system

- HIE-ISOLDE 1
  - Energy upgrade up to 8-10 MeV/u with a superconducting linac, beam quality improvements and the design study of the intensity upgrade
    - R&D activity for LINAC funded
- HIE-ISOLDE 2
  - Intensity upgrade for 30 kW on target
    - Linac 4 beam via PSB and Light SPL beam to ISOLDE
  - Super-HRS

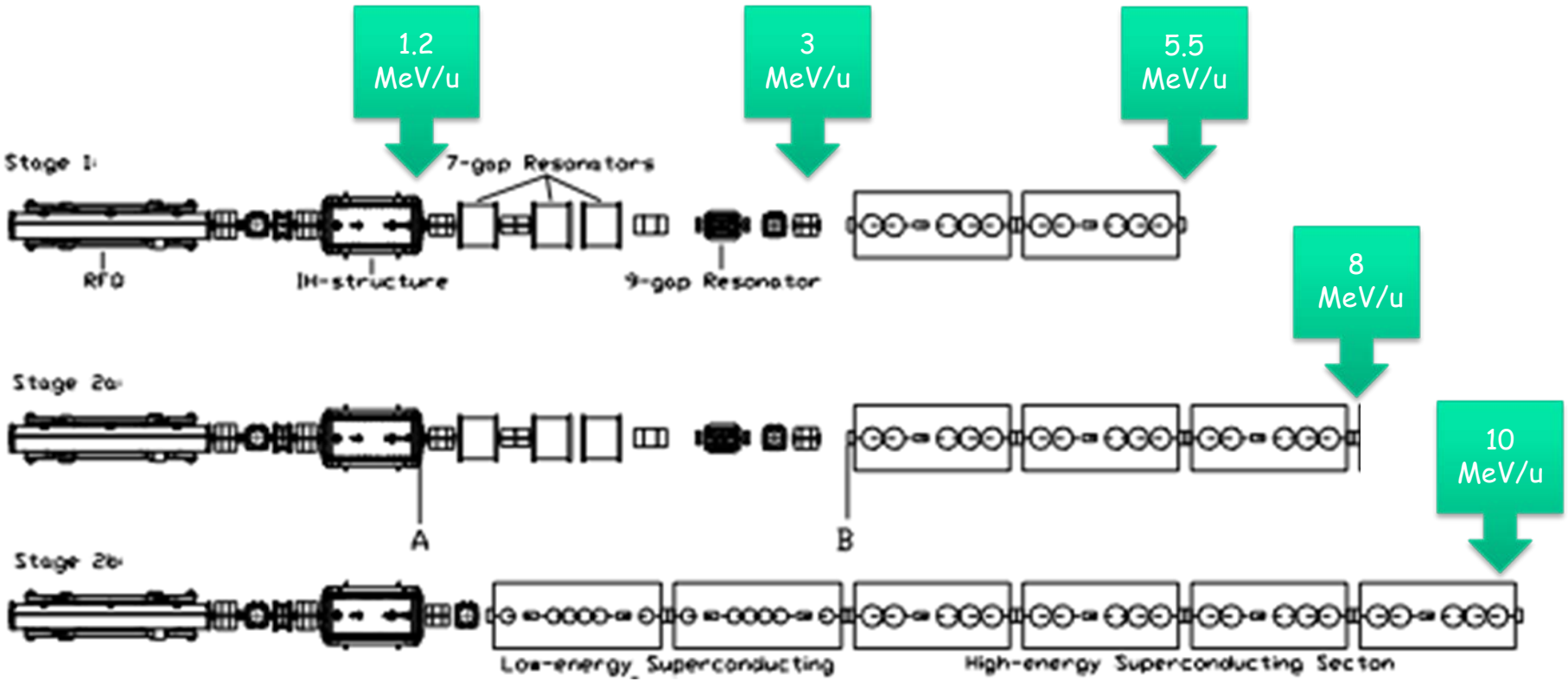
Existing REX-ISOLDE linac – a world leading RIB facility





HIE-ISOLDE LINAC - layout

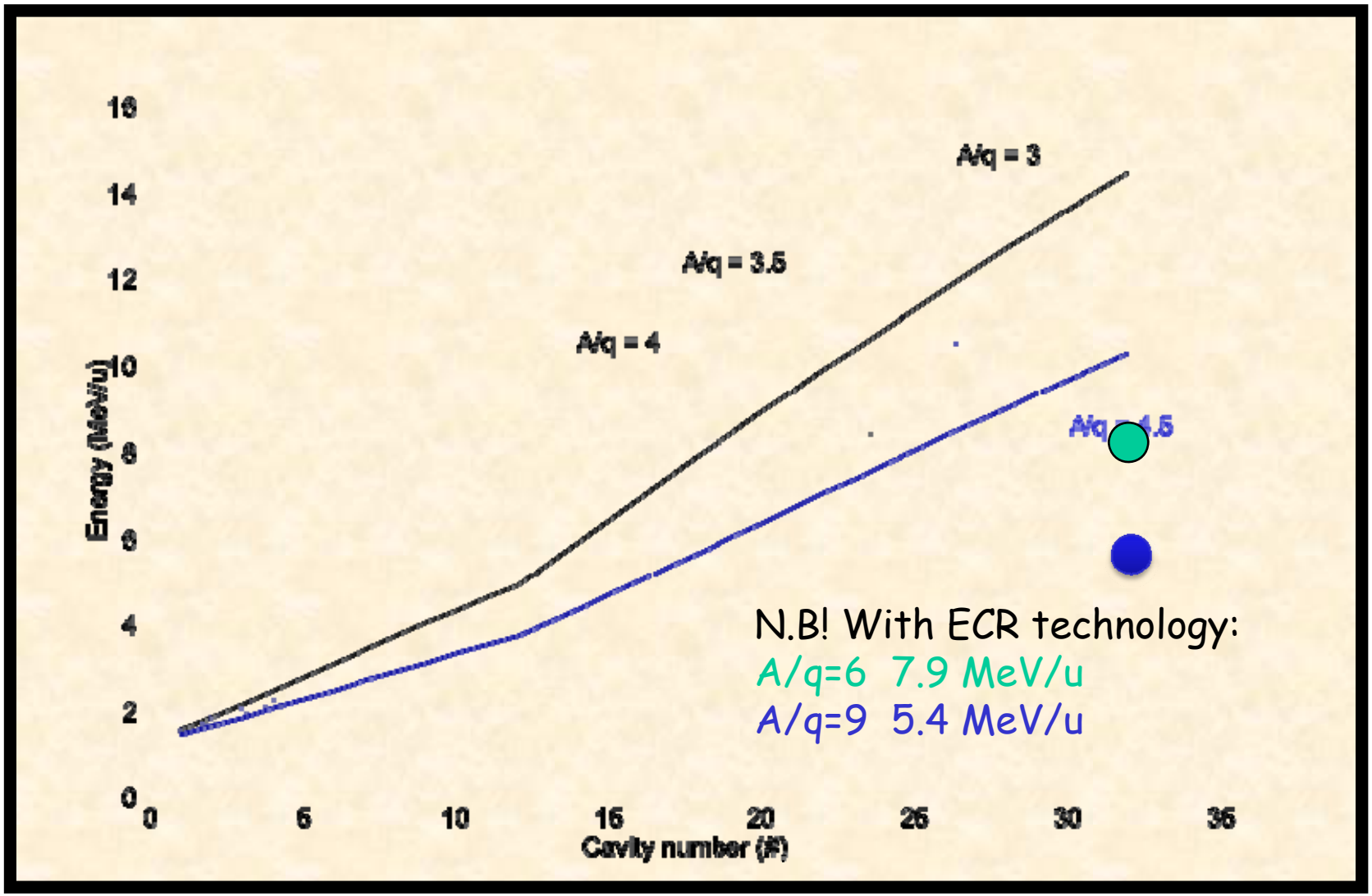
3 stages installation



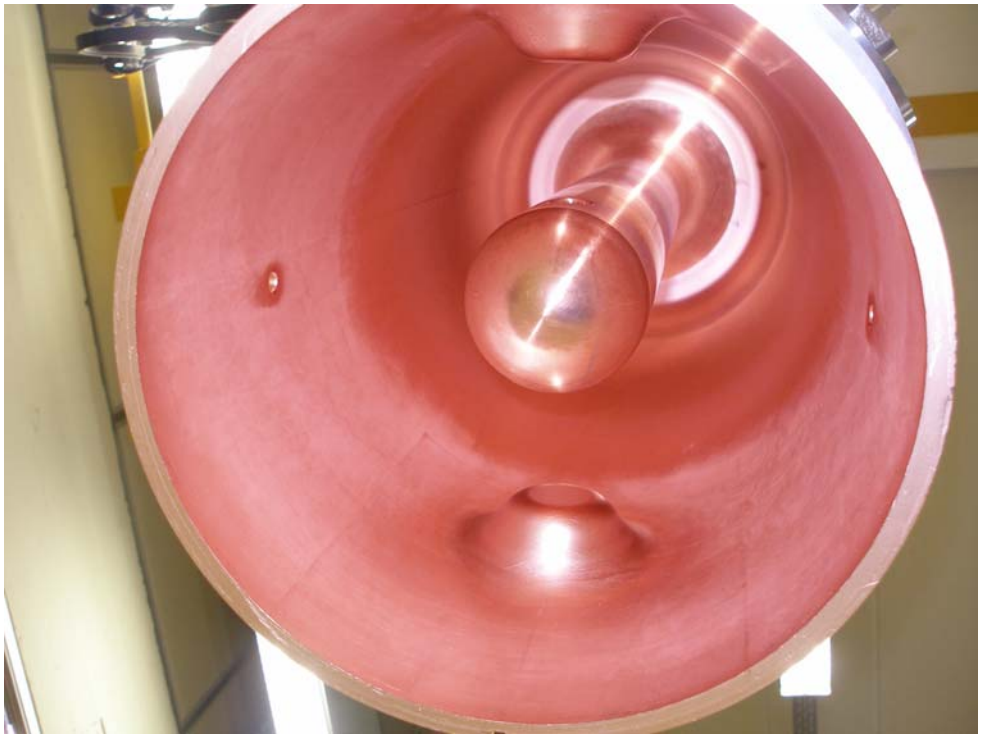
HIE-ISOLDE SC-linac

- SC-linac between 1.2 and 10 MeV/u
- Energy fully variable; energy spread and bunch length are tunable. Average synchronous phase ϕ_s= -20 deg
- 2.5<A/q<4.5 limited by the room temperature cavity
- 16.02 m length (without matching section)
- No ad-hoc longitudinal matching section (incorporated in the lattice)

Final Beam Energies

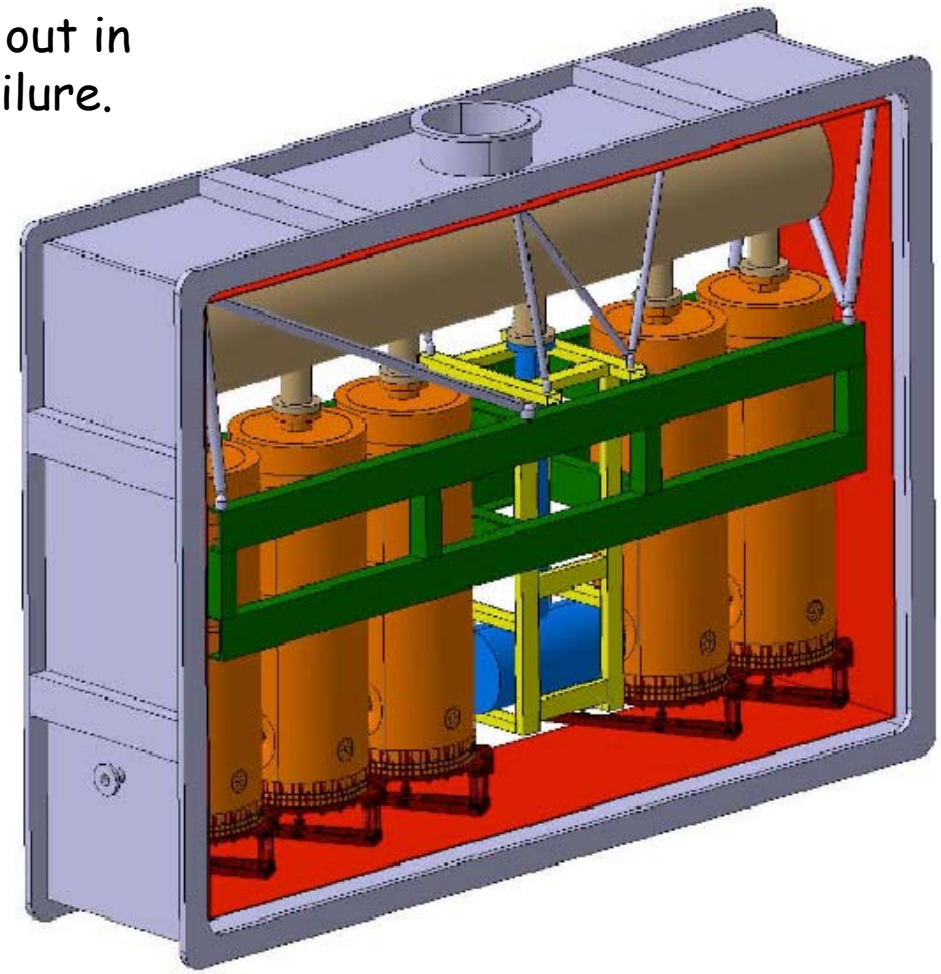


Cavity prototype



Cryomodule design

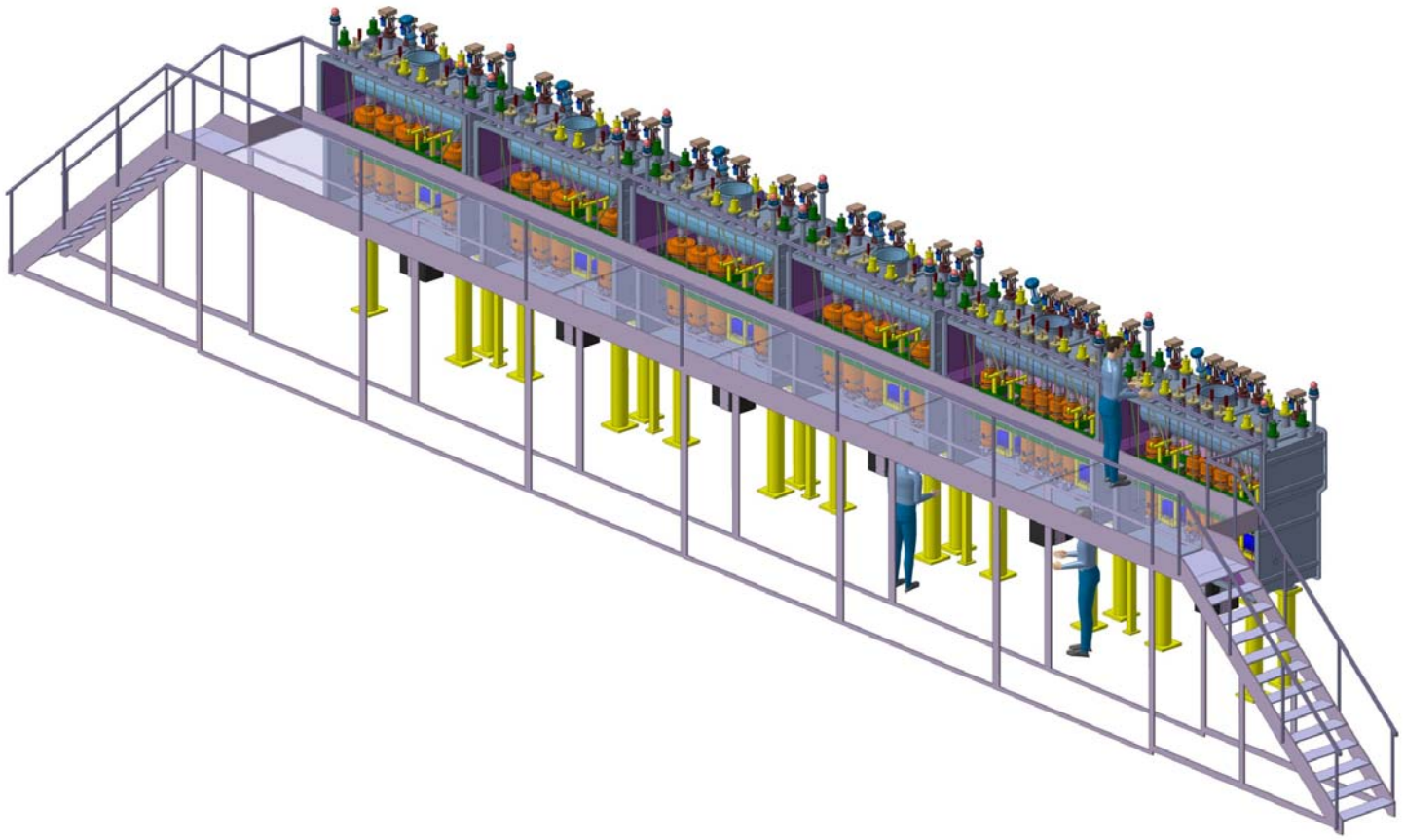
Each cryomodule can be isolated and taken out in case of failure.



Common vacuum concept to minimize the inter-cryomodule distance

This concept foresees the possibility to align the solenoid when cold from the outside (beam alignment)

HIE-ISOLDE SC linac



DOE proposal - Comparison EBIS/ECR/1+

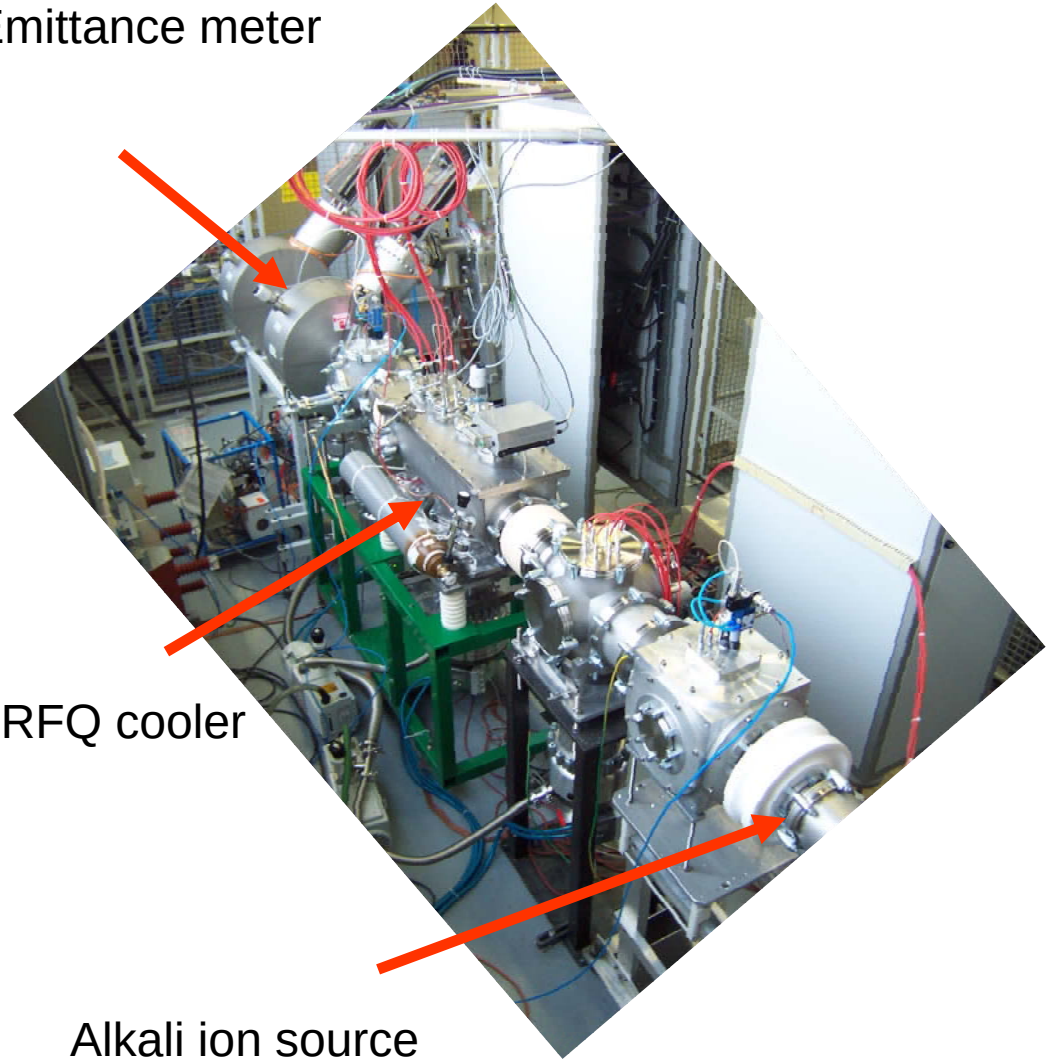
		Proposed high-intensity EBIS/T breeder	Next-generation ECR breeder	1+ scheme with stripping	Gain EBIS/T vs ECR	Gain EBIS/T vs 1+
Efficiency for single charge-state re-acceleration	ε (A<40)	> 60 %	< 20 %	<40%	>3	>1.5
	ε (A=100)	> 50 %	< 20 %	<10%	>2.5	>5
	ε (A=200)	> 40 %	< 20 %	<5%	>2	>8
Chance of reaching 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/cm^2)	$<10^5$	$<10^4$	$<10^4$	<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.

RFQ cooler "ISCOOL" - DONE
EPSCR grant (Manchester, Birmingham)

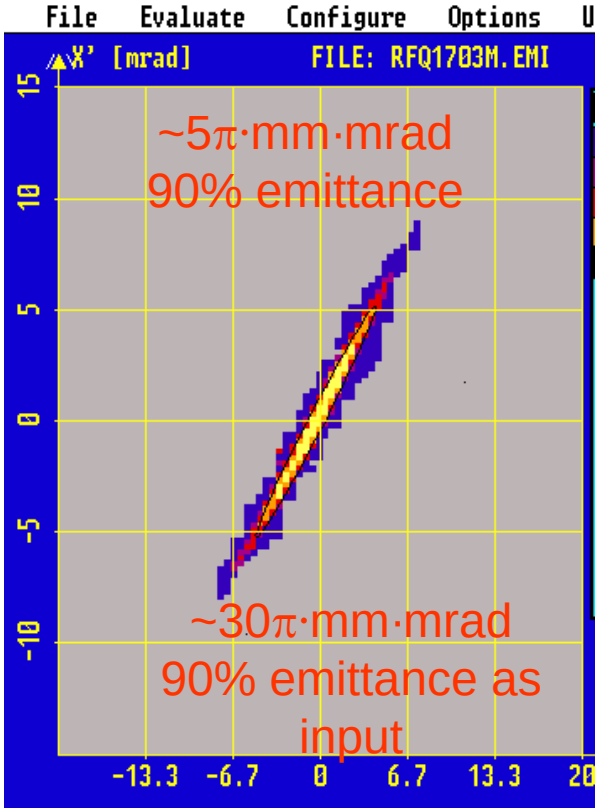
Emittance meter



RFQ cooler

Alkali ion source

Continuous mode



Ion	transmission
Li^+	17%
Na^+	27%
K^+	60%
Cs^+	70%

The Resonance Ionization Laser Ion Source

RILIS beams of 28 elements are available so far:

elements available at ISOLDE LIS

ionization scheme tested

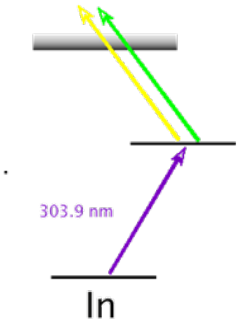
ionization scheme untested

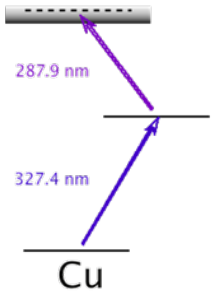
1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Rf	105 Ha	106 Sg	107 Ns	108 Hs	109 Mt	110	111	112						

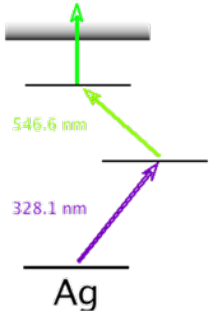
58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

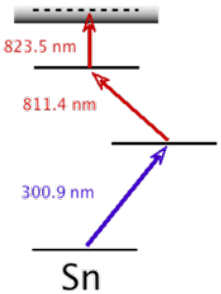
4 types of ionization scheme:

2-step: (1 resonance) (2 resonance) 3-step: (2 resonance) (3 resonance)









New Nd:YAG lasers at ISOLDE RILIS - DONE

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

CVL → **SSL**

15 ns @ 11 kHz | **8 ns @ 10 kHz**

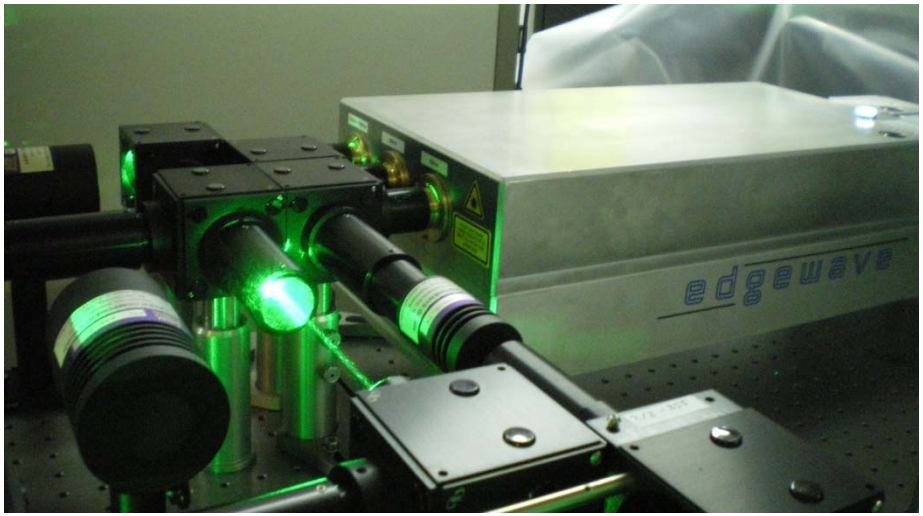
Green Beams
45 W @ 511 nm

Yellow Beams
35 W @ 578 nm

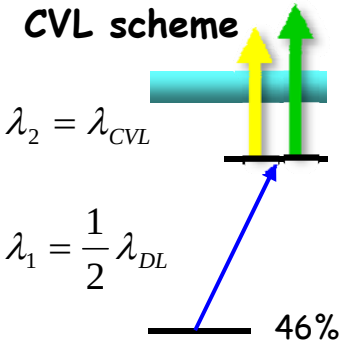
Green Beams
90 - 100 W @ 532 nm

UV Beam
18 W @ 355 nm

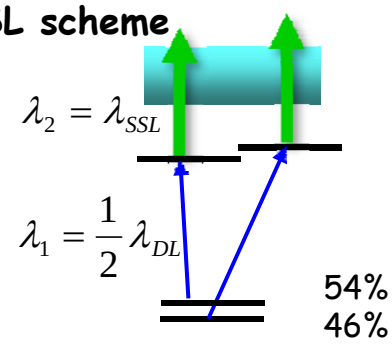
IR Beam
35 W @ 1064 nm



CVL scheme



SSL scheme



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**

Knut and Alice Wallenberg foundation grant

Road map of RILIS upgrade

2008

- Installation of solid state lasers for dye laser pumping. Keeping CVL lasers at RILIS as backup until reliable SSL performance is reached.

2009

- Upgrade of dye lasers: purchasing and installation of commercial dye lasers

2010

- Installation of solid-state tunable lasers with own pump laser in addition to the dye laser system

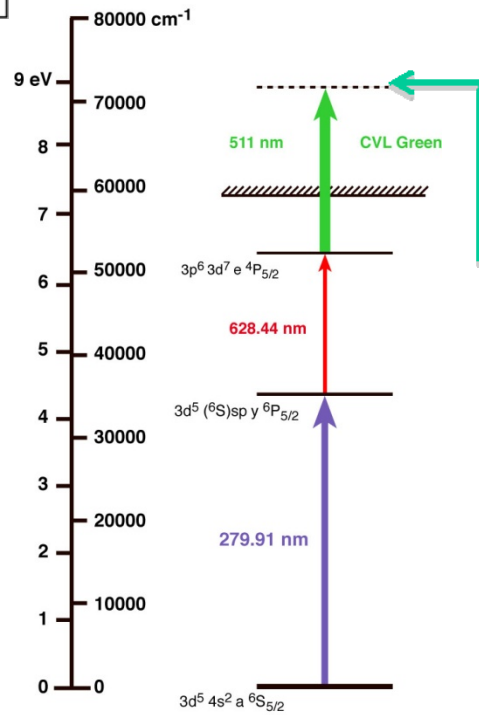
2011

- Duo-RILIS: two laser systems available for operation with a possibility of quick switch from one element to another

Knut and Alice Wallenberg foundation grant

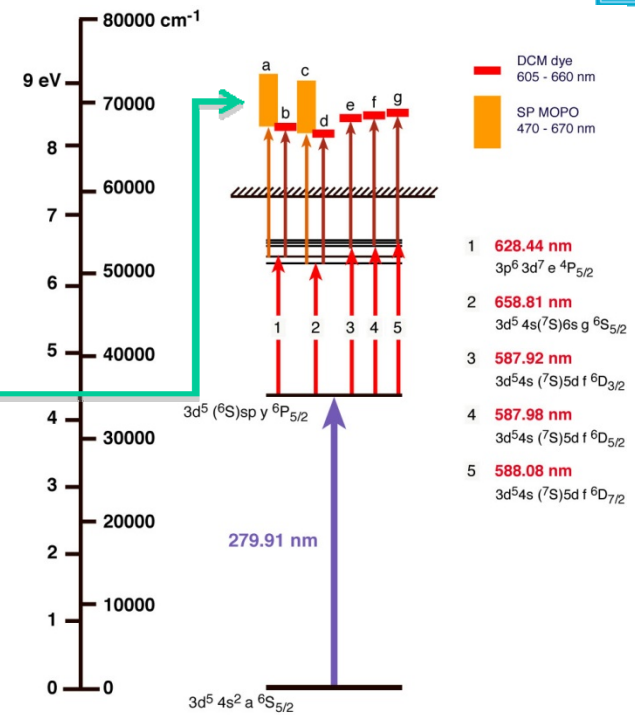
LARIS results – A new RILIS scheme for Manganese - DONE

- Replacement of current scheme which uses the CVL green beam.



Fortuitous
Auto-ionizing transition
at CVL wavelength

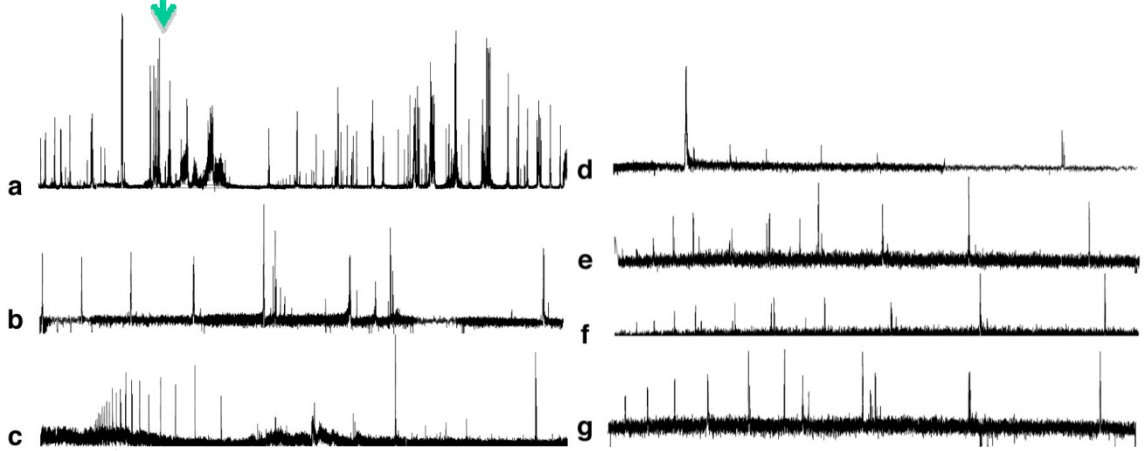
AIS search at LARIS



Outcome of RIS study of Mn at LARIS:

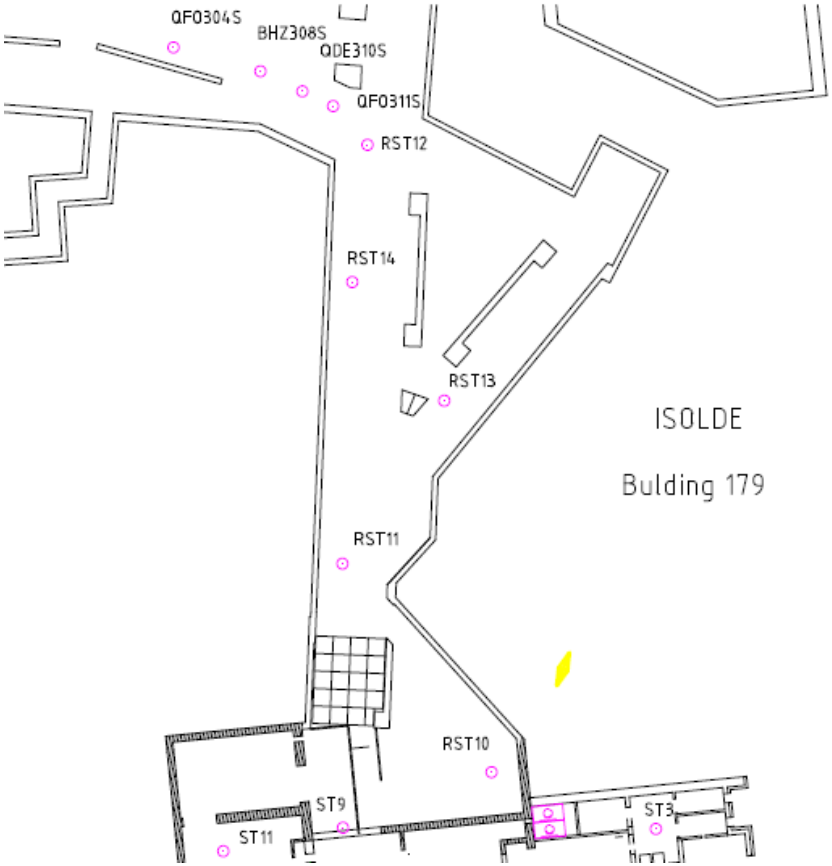
Many new auto-ionizing states found

Various promising Nd:YAG based schemes tested and ready for efficiency measurement at RILIS

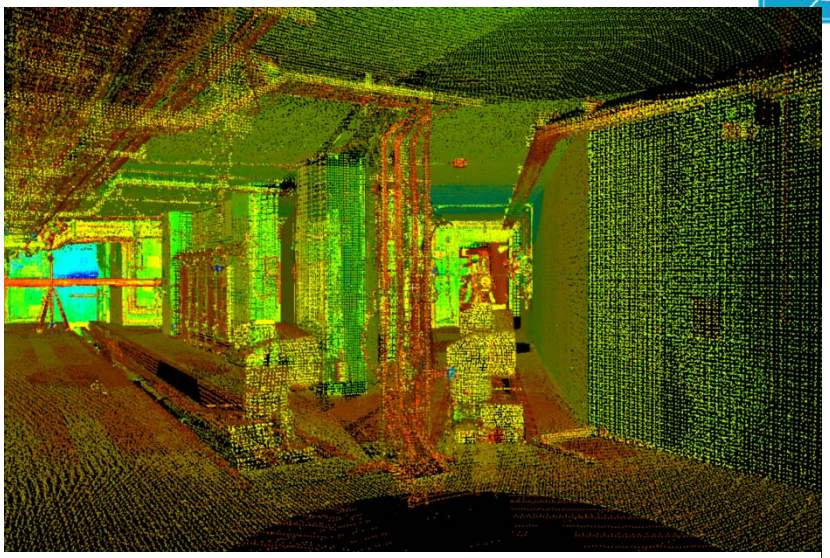


Knut and Alice Wallenberg foundation grant

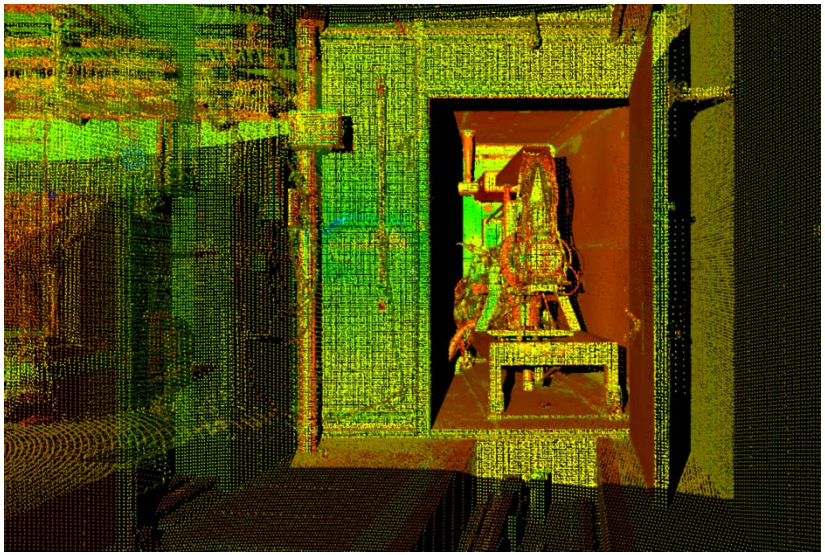
ISOLDE target area - The 3D Laser Scan



Reference Points



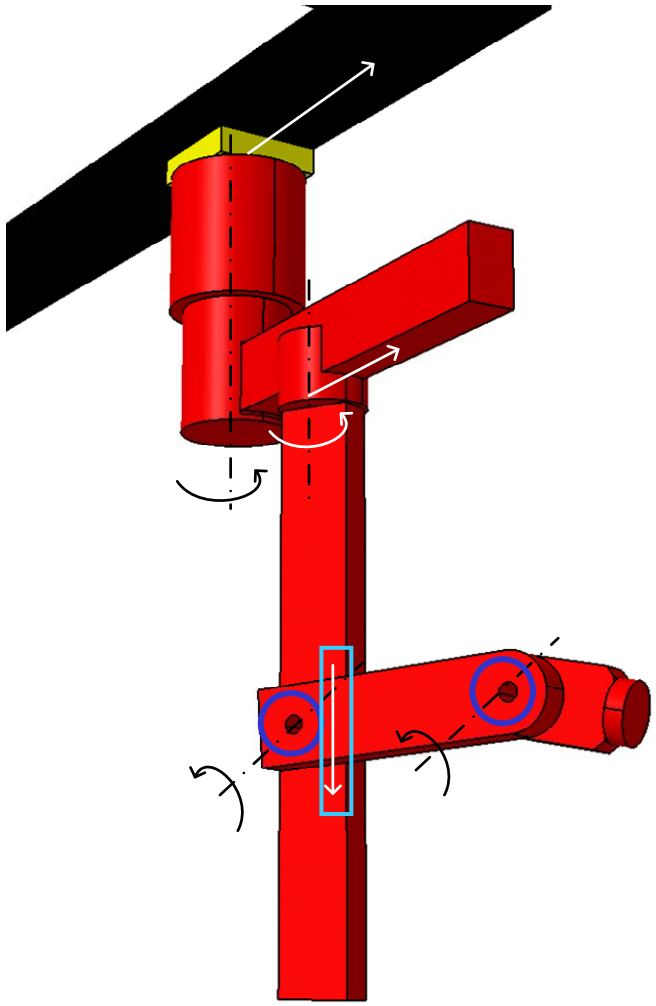
Cloud of point in the CERN coordinate system



May, 2008

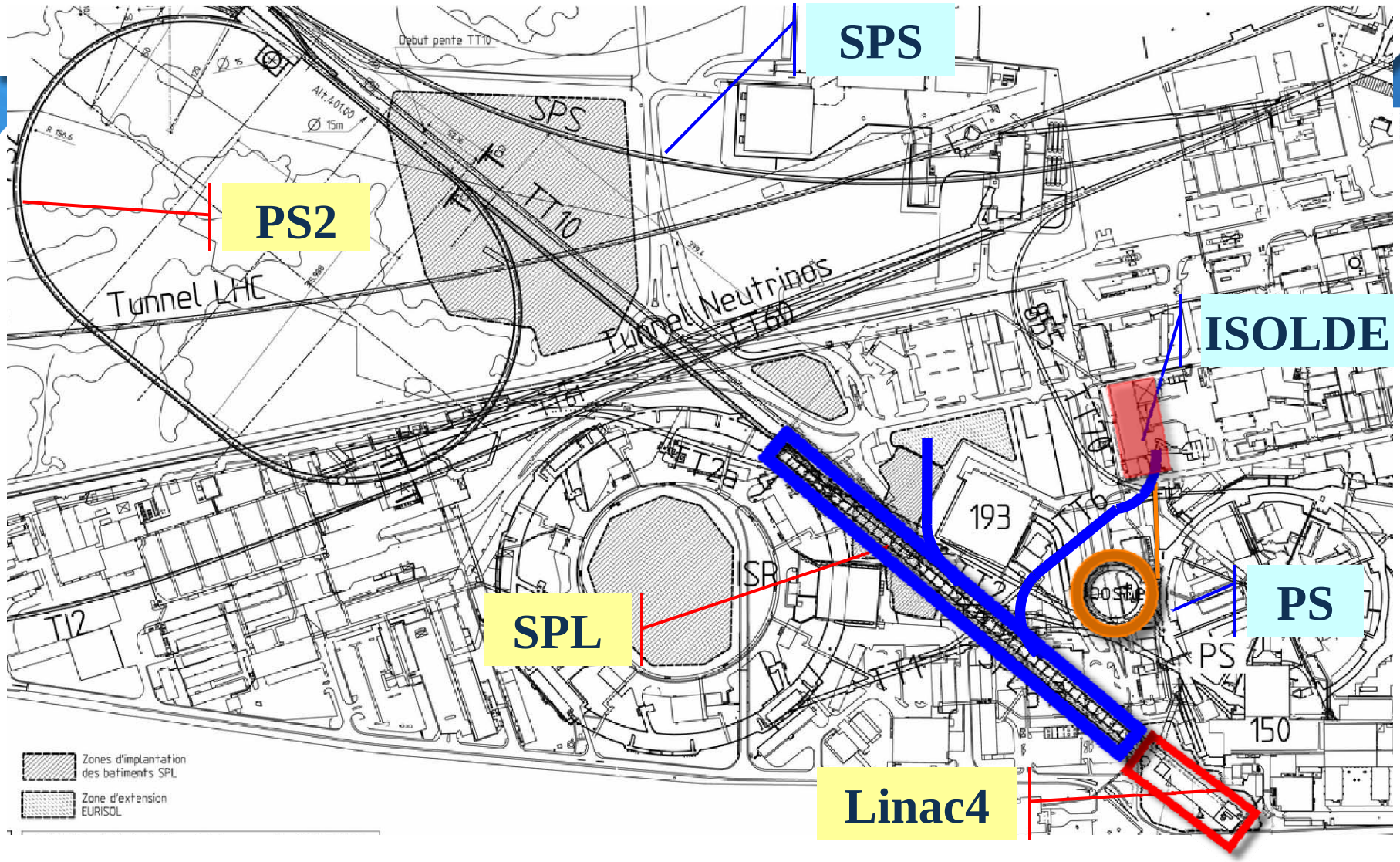
J. Sarret, L. Bruno

Manipulator concept design



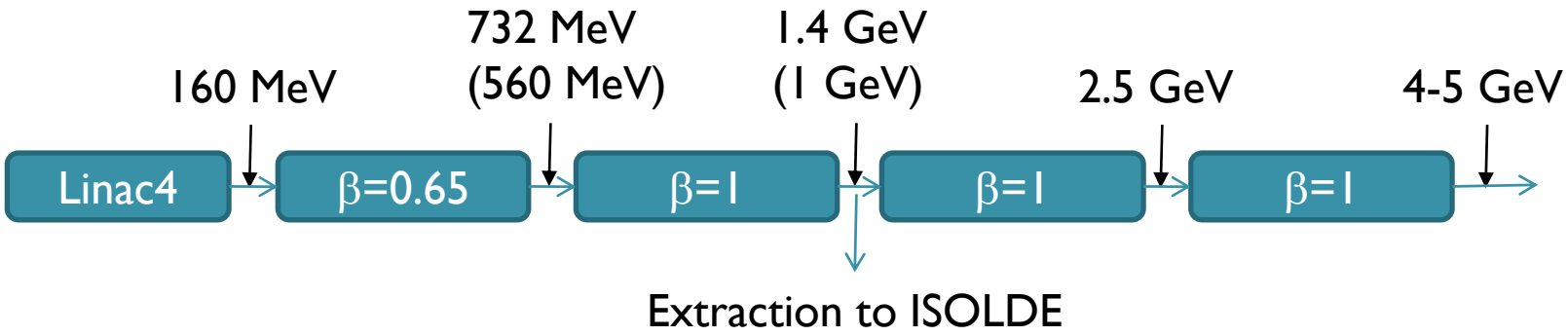
- 6-DOF Manipulator mounted on ceiling monorails
- Equipped with tool changer for mounting different tools
- Recoverable by decoupling (remotely) rail gear drive
- High lifting capacity (FFE)
- Target & electrode accurate / sensitive operations

Overall layout of the new injectors (1/2)



Analysis

- **SPL block diagram**



- **Main impact of faster cycling rate: klystron modulators (SPL + Linac4)**

Limited $P_{average}$ + technology limited cycling rate (~ 15 Hz)

$P_{average} \propto$ Modulator pulse length x Rep. rate

$P_{average} \propto$ (Modulator rise + Cavity fill + Beam pulse) x Rep. rate

200 μs

$\propto E_{acc}^2$

- Other consequences of faster cycling rate:
  - Magnets power supplies
  - Beam instrumentation
  - Controls…

Minimum cost options

⇒ LP-SPL type modulators ($P_{nominal} \equiv 0.35$ % duty cycle)

*** Basic period : 600 ms – PS2 cycling time: 2.4 s**

Baseline solution

Beam energy (GeV)	Max. pulse duration (ms)	Max. current during pulse (mA)	Cycling rate* (Hz)	Max. protons /pulse ($x10^{13}$)	Max. beam power (kW)
1.4	0.9	20	1.25 (3 out of 4 pulses)	11	31
1	0.35	28	2.92 (7 out of 8 pulses)	6.1	29

Need for wide range high power RF phase shifters… => Cost!

Summary

- Planning for a staged implementation project
- HIE-ISOLDE 1
  - HIE LINAC R&D within the EUCARD I3 and with Belgium grant is making good progress
  - Test of the first cavity for the SC linac are expected in June/July at TRIUMF in Vancouver
  - On-going beam quality development e.g. RFQ cooler and RILIS
  - Construction of linac and design study of new target area
- HIE-ISOLDE 2
  - Construction of new target area and Super-HRS
  - Linac 4 (10 kW) and LP-SPL (30 kW)