Radiation protection study for the HIE-ISOLDE post-accelerator

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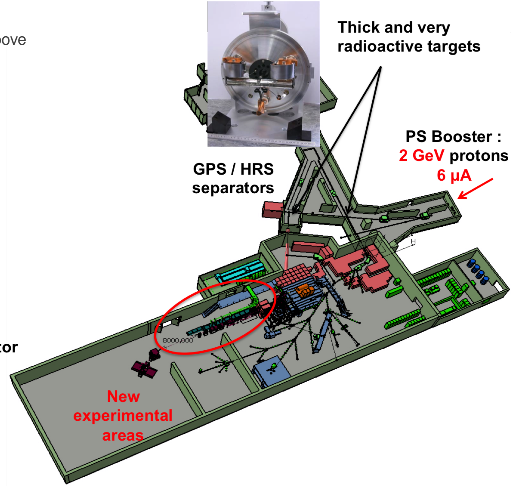
Energy upgrade : RP hazards increase at HIE-ISOLDE

- Neutron emission

beam losses for ions accelerated above the Coulomb barrier (low intensity)



REX-ISOLDE post-accelerator replaced by a SC linac
Energy above the Coulomb barrier
for most target/projectile combination

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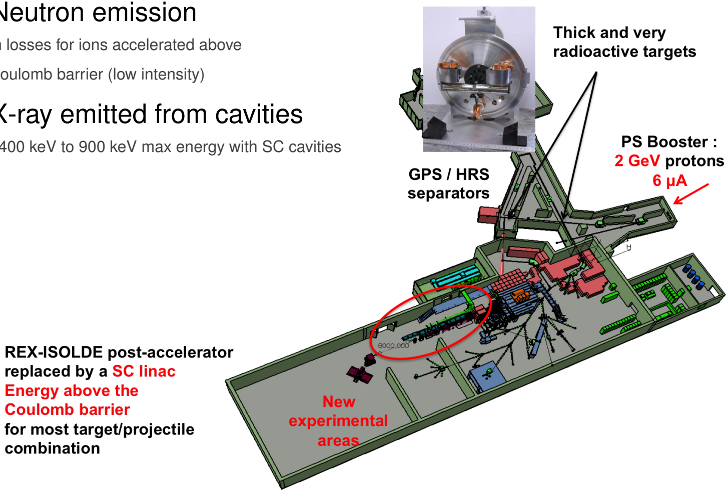
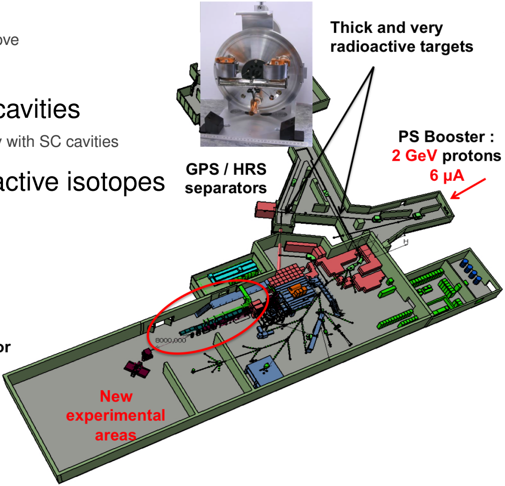
- **X-ray emitted from cavities**

  from 400 keV to 900 keV max energy with SC cavities



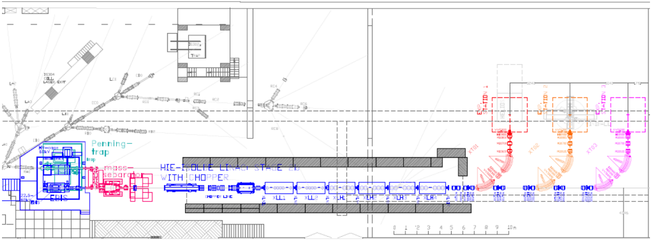
Energy upgrade : RP hazards increase at HIE-ISOLDE

- **Neutron emission**
  beam losses for ions accelerated above the Coulomb barrier (low intensity)
- **X-ray emitted from cavities**
  from 400 keV to 900 keV max energy with SC cavities
- **Production of radioactive isotopes**
  existing at ISOLDE



REX-ISOLDE post-accelerator replaced by a SC linac Energy above the Coulomb barrier for most target/projectile combination

Constraints and challenges

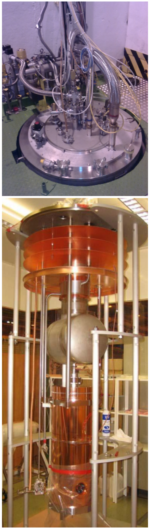


- Accelerator inside the experimental hall
  - + keep the current classification of the area
  - + maintain the X-ray background at low levels
- Consider space constraints and integration of all services necessary (HV, RF, He supply and exhaust)
- Define the radiations source term for shielding design

Strategy

- Review of existing similar facilities (Triumf & Legnaro)
  $\Rightarrow$ X-rays identified as the main radiological hazard
  (low intensity beams compared with ISAC2 where the experimental hall is accessible)
- Measurement of X-rays emitted by RF cavity prototypes (depends on cleanliness and surface state of the Nb deposit)
- Conservative approach to extrapolate the maximum dose rate for the operation of several cavities in parallel
- FLUKA calculations with a detailed layout of the shielding enclosure to identify possible weaknesses and access restrictions

X-ray emission : measurements



Nb/Cu cavity on its test frame

3 RF modes of operation / max dose rates measured (ionisation chamber)

a) Normal operation (Q_0 measurement) : **20 mSv/h**

b) Normal cavity conditioning : **20 mSv/h**

c) He processing for cavity conditioning : **350 mSv/h**

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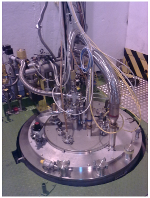

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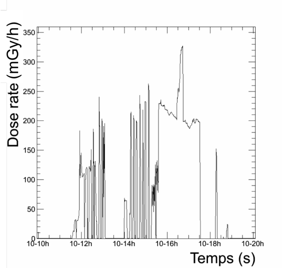
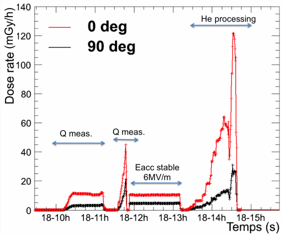
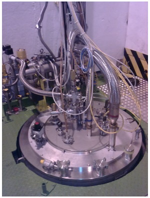


He processing of one cavity at SM18



Measurements at different angles for different modes of operation

X-ray emission : test bench simulations



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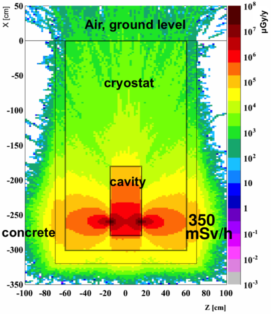


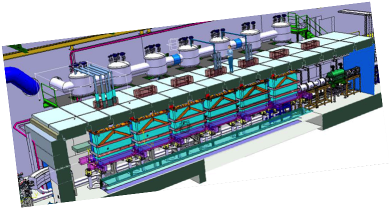
Test bench implemented in FLUKA

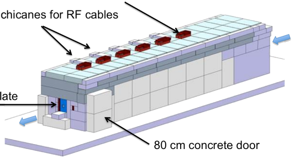
- Generating e- beam at 900 keV (max energy) impinging on cavity wall
- Dose rate normalized to 350 mSv/h at monitor position
- $I_0 = 8 \times 10^{13}$ (e-/s)

Simulation of a RF cavity in the cryostat during He processing

FLUKA calculations for the shielding

Detailed geometry of the tunnel implemented in FLUKA (penetrations, doors...)





Objectives of Monte Carlo simulations

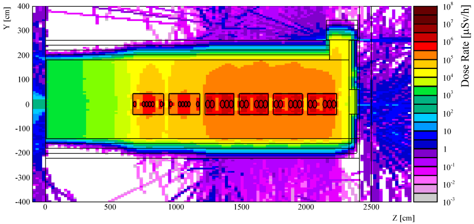
- Validate shielding requirements : design objective for the bulk shielding remain below 1 μSv/h due to X-ray from cavities
- Identify possible weaknesses

FLUKA simulations for X-rays

Source term

- 600 keV / 900 keV (low / high beta) electrons randomly distributed between 32 cavities
- Normalisation factor from SM18 conditions for He processing in all cavities (pessimistic)
- Normal operation and conditioning dose rates should be lower by at least a factor 10

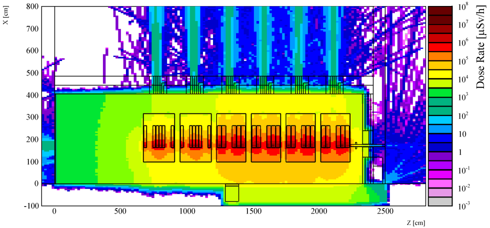
He processing of 32 cavities
Horizontal cut at beam axis height



FLUKA simulations for X-rays

- Many penetrations on the roof (empty in the geometry)
- Hundred of μSv/h on the roof during He processing :
  - **No access to the roof during RF operation**
  - Could be relaxed if acceptable levels measured

He processing of 32 cavities
Vertical cut, beam axis



Shielding status

Lateral concrete blocks have been delivered and installed

Assessment of the up-beam part of the shielding ongoing
(1 cm of lead today)

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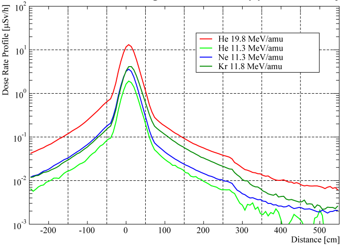
Free access to the experimental hall at all time

Ion beam losses

Dose rates ($\mu Sv/h$) at 1m and 90 degree

Beam	A/q	Energy (MeV/u)	Intensity (ppA)	Neutron dose rate (uSv/h)	Comment
?	2	19.8	1	<1	Radioactive beam (limit case)
Ne5+	4	11.3	4	1	Stable pilot beam
N4+	3.5	12.6	5	2	Stable pilot beam
He2+	2	19.8	10	9	Stable pilot beam
Ne5+	4	11.3	200	50	High intensity stable beam

Dose rates at 90 degree for a 1 ppA intensity



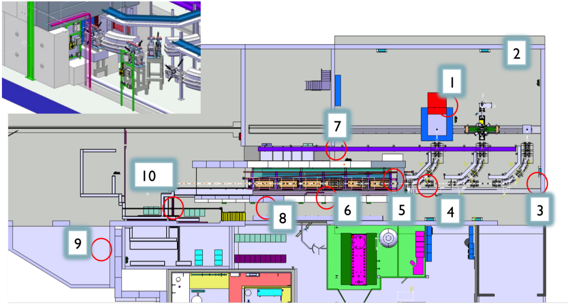
For ion beam intensities foreseen at HIE-ISOLDE (< 20-30 pA)

- Very low intensities for physics with RIBs
- For beam tuning of the machine with stable beams, higher intensities can lead to higher dose rates
  $\Rightarrow$ small exclusion areas around beam losses spots (a few hours during specific beam tuning)

Radiation monitoring system

Monitoring system around the post-accelerator

- XRM (X-ray monitor) for pulsed x-ray
- AMF (Area Mixed Field Radiation monitor) for n, γ



Conclusion and perspectives

What was done up to now

- Comparison with existing facilities ⇒ X-ray main hazard
  - + Maximum dose rate for different cavity operation phases
  - + Conservatism in the approach used (max e- energy, prototype performances, all cavities conditioned in parallel)
- Ion beam intensity much lower than at ISAC2 (TRIUMF) with the hall accessible to users
- RP monitoring designed for X-ray and higher beam energies

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In the future

- Existing hazards and corresponding RP procedures will remain (contamination risks when opening the vacuum system and dose rate in case of strong gamma emitters beam loss or collection)
- Future studies to assess the activation/RIB implantation for beam intercepting device (waste studies. . . .)

Thank you for your attention

Thanks to the HIE-ISOLDE collaboration

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