CERN

Linac4 Continous Caesiation Risk Assessment for the RFQ

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Introduction

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Linac4 RFQ Risk Analysis

In 2015 a general risk analysis for the Linac4 RFQ has been undertaken on the basis of internal and external experience – as available in 2015.

Experience with caesiation at other laboratories:

- JPARC: An RFQ is a “consumable”. RFQ #3 in operation. – Used as dump for 20% of beam. Issues not Cs related.
- SNS: 3 “detuning” incidents, purchased spare. Sparking issues, believed not to be Cs related.
- ISIS: Caesium incidents in source and cold-box. No sparking issues or Cs contamination in the RFQ.

Linac4 RFQ Risk Analysis

Two potential risks in relation to caesiation have been included in the analysis:

RFQ electrode contamination due to Cs deposition:

- Normal Caesiation
  - Probability: once in 1-5 years (likely)
  - Impact: beam stop < 1 hour (negligible)

- Caesiation Accident (Cs in source: 25 mg)
  - Probability: once in 30-50 years (very rare)
  - Impact: 1 week < beam stop < 2 months (critical)

Linac4 RFQ Risk Analysis

A mitigation was proposed and has been implemented:
A hard-wired interlock from the vacuum valve to Cs oven.

RFQ electrode contamination due to Cs deposition:

- Normal Caesiation
  - Probability: once in 10-30 years (rare)
  - Impact: beam stop < 1 hour (negligible)

- Caesiation Accident (Cs in source: 25 mg)
  - Probability: once in >50 years (very very rare)
  - Impact: 1 week < beam stop < 2 months (critical)

Linac4 RFQ Risk Analysis

Spare RFQ options:

	Option	Approximate cost (kCHF)	Time required to replace running RFQ in case of need
1	Build full spare RFQ	1’630*	2 weeks
1.1	*Operational costs for a hot spa on the test stand*	*0.5 FTE + 50 kCHF/year*	
2	Build spare module 1 + rough machining + procure all material	800	3 weeks to replace module 1 12 months to complete RFQ
3	Rough machining + procure material	400	20 months to build RFQ
4	Procure copper and special steel for full RFQ	350	24 months to build RFQ
5	Do nothing	0	32 months to build a new RFQ

Linac4 RFQ Risk Analysis

Conclusions (1):

While the fabrication of a complete spare RFQ has been recommended by colleagues working in similar laboratories worldwide and for different reasons, the present risk analysis indicates that, thanks to the less demanding operating conditions at CERN with respect to other laboratories and to the robust design and construction of the Linac4 RFQ, **all envisaged failure scenarios could be repaired in a time comparable to what is required for the installation of a spare**, once a series of mitigation measures are adopted.

It should be however observed that additional risks not included in the present list could appear, and that for the evaluated risks the **error bars are quite large as usual in this kind of exercises, in particular when it comes to evaluating risks with low probability and high impact**.

Linac4 RFQ Risk Analysis

Conclusions (2):

For this reason, some preparation for an emergency construction or repair of the RFQ should be started, considering that CERN is equipped with high-level workshops that could immediately start the construction of an RFQ in case of need, and that most of the failure scenarios considered in this paper have long time constants. In most cases construction of a spare could be decided after the appearance of the first symptoms of a problem and still completed before any degradation of the LHC beams. Solutions could be adopted going in the direction of reducing the long RFQ construction time.

The availability of a spare RFQ would be valuable and better justified in the frame of maintaining a full 3 MeV front-end available for beam studies and developments for e.g. improving p and H- ion sources. In this case, appropriate resources should be allocated for the operation of the Test Stand.

Continuous Caesiation

Verify potential consequences of the implementation of continuous caesiation on the risk analysis:

- Increase in **Probability** for Cs deposition in the RFQ?
- Increase in **Impact** in case of a caesiation accident?
  - The frequency of such an event and the amount of Cs entering the RFQ are external parameters.
  - To be answered by source and vacuum experts.

Additional Caesiation References

Frankfurt University / GSI:
Gerhard et al.: “RF Sparking Experiments”, 1985

- Tests undertaken on vane and rod RFQ test structures.
- Cs vapor halves electrode voltage standoff.
- Effect of Cs disappears after hours of reconditioning.

DESY / HERA:
J. Peters: “H- ion source activities at DESY”, 1993

- Multipactoring in DTL and glow discharge in RFQ.
- No traces of Cs in RFQ and DTL but on cold-box window.

Additional Caesiation References

Russian Academy of Sciences, Tomsk:

D. V. Chudinov et al: “Interactions of Surface States of Copper with Transition Metals and Cesium”, 2003

- No more than 1 monolayer of Cs can be deposited on the surface of metals or semiconductors at room temperature, since the heat of adsorption is very small.

This is not a new finding but has already been reported in earlier references.

Consider that 1 monolayer of Cs distributed on all the inner surface of the RFQ corresponds to ~5 mg of Cs.

Additional Mitigation Options

Reconditioning of a Cs contaminated RFQ appears to be a working strategy.

However the references are limited and information on the amount of contamination is unavailable.

In absence of more detailed information three approaches could be considered:

- Studies on a test cavity.
- Analysis of vacuum processes (desorption, electron bombardment, glow discharge).
- Accept risk and go for a heuristic approach.
- Any kind of combination of the previous.

Additional Mitigation Options

Studies on a test cavity:

- Currently no test cavity with RF system is available.
- The related work is considerable and not foreseen.

Analysis of vacuum processes (desorption, electron bombardment, glow discharge):

- This is a subject for vacuum experts.

Linac4 RFQ Cleaning Strategy

Accept risk and go for a heuristic approach:

- One would try to recondition the cavity.
- There is no indication on the time this could take.
- One would try for hours, days, maybe a week.
- If an improvement is seen, one would continue.
- Maybe the RFQ can be operated intermittently.
- If no progress is seen, the RFQ could be cleaned by water rinsing (4 weeks if planned ahead).
- Or exchanged if a spare RFQ were available (2 weeks with a hot spare).

Linac4 RFQ Spare Strategy

Is building a spare RFQ justified?

- Costs for a hot spare is ~2-3 days of LHC operation.
- Installation time of a hot spare is 2 weeks.
- If the Probability and Impact are not increased, the 2015 Risk Analysis is valid for continuous caesiation.
- All envisaged failure scenarios could be repaired in a time comparable to what is required for the installation of a spare.
- A spare RFQ could help further reduce risks. Difficult to justify without increased risk score, or new optics.
- Only way to get <1h: with second front-end on linac.

Conclusions

- 2015 Linac4 RFQ Risk Analysis is still valid in general.
- Input required to evaluate continuous ceasiation risks.
- No severe RFQ caesiation incidents found in literature.
- Described potential mitigation options.
- Described a heuristic cleaning strategy.
- Reconditioning is expected to work, but…
- In case that reconditioning does not work, 4 weeks for RFQ water rinsing required (if planned ahead).
- A spare RFQ (if available) could be installed in 2 wks.

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