The SPES RIB Safety System: main guidelines

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On behalf of SPES safety WP
SPES TAC1 meeting, LNL, January 2014

Outline

1. How to analyze and work out the SPES safety issues
   - What **we do and how** in order to meet the required safety criteria for SPES facility
2. Tools used to set up and manage the SPES safety
   - How to classify the consequences of an accident, to rank a risk, to decide when to take action to reduce it and how to perform interventions.
3. Sharing of experience in managing safety issues of still running RIB facilities
   - Is a crucial issue for the best operation of facilities like SPES. Comments/opinions are welcome

The safety framework

Artistic View of the facility

SPES facility will be characterized by different installed equipment, each one causing potential critical events.

A comprehensive study of the safety aspect is therefore needed.
A high degree of reliability must be achieved to prevent hazardous situations for operators, population, and the surrounding environment.

For the INFN SPES project, is going to be realized:

a) Quality and Safety Management System (**QSMS**)

b) Radiation Safety System (**RSS**)

The QSMS for SPES

Goal: setup and implement a Quality and Safety Management System (QSMS).

QSMS is a managing tool to achieve an high quality and safety standard for SPES, by drafting all the following phases of the SPES lifecycle:

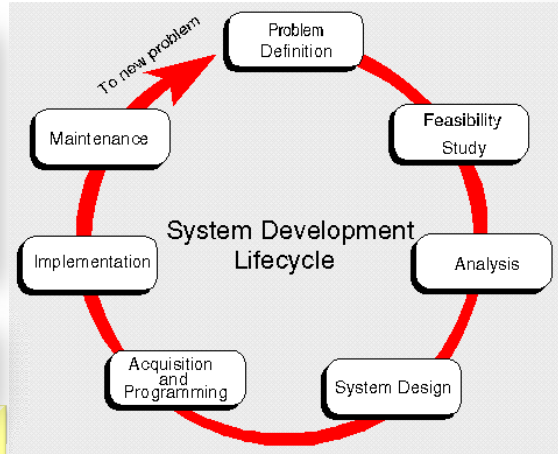
- Design
- Construction
- Operation
- Maintenance
- Dismantling

Every stage analyzed to focus activities/operations that should be controlled to guarantee the required

Safety

Quality

for safe operation of SPES facility



The QSMS is implemented according to:

- Italian safety laws and regulations
- International technical standards
- Mandatory prescriptions that the project must comply

Main Reference international Standards

ISO 9001:2008 for all **Quality aspects**

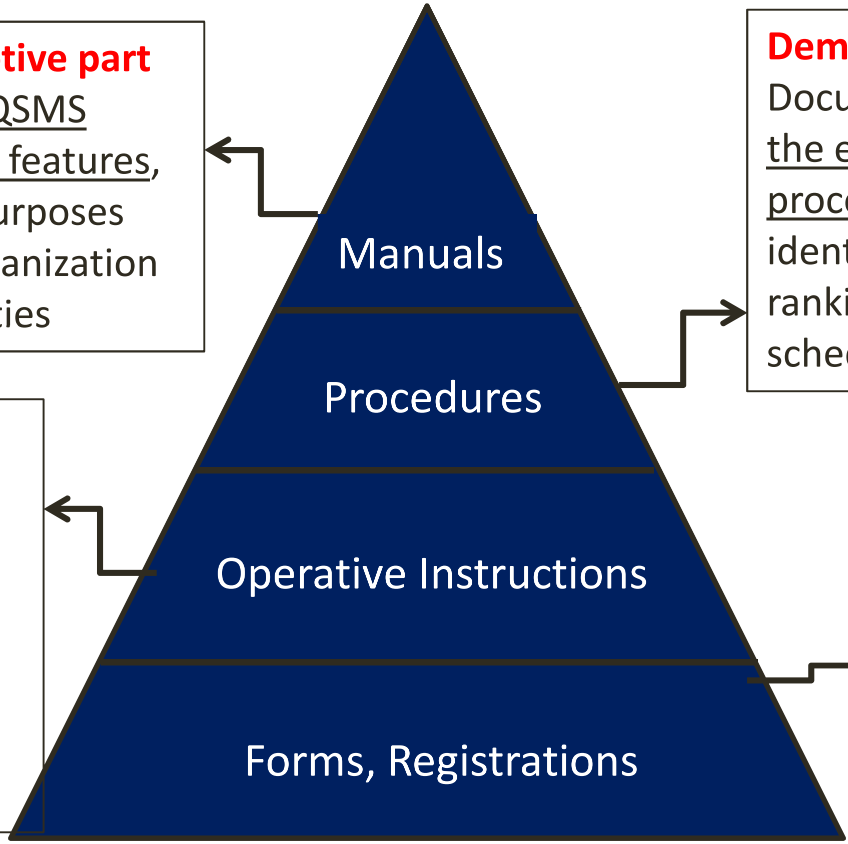
OHSAS 18001:2007 for **Safety issues**

The SPES QSMS main docs

Documents of the **QSMS** are hierarchically organized according to a pyramidal scheme, collected and catalogued according to specific storage rules for quick retrieval

Descriptive part
of the QSMS general features, main purposes and organization modalities

Demonstrative part
Documents containing the established procedure for risk identification and ranking for any single schedule activity



Exploitation part
Collection of technical notes, operational procedures and maintenance protocols to be used.

Probative part
Maintenance reports, intervention descriptions, inspections and operations logging to be recorded at the end of each activity.

Such a problem solving approach is mandatory as regards the implementation of the **Risk Analysis for critical components of the SPES facility**

SPES facility Safety Analysis guidelines

- **Main goal:** detailed identification of **all hazards and related risks assessment** due to the SPES facility operation (i.e. all experimental apparatuses yielding (prompt & delayed) radiation hazards)

Methods adopted:

1. For a general analysis of the system components the following standards is being used:
   ISO 12100/2010:
   Safety of machinery – General principles for design – Risk assessment and risk reduction

   ISO 14121:2/2007
   Safety of machinery – Risk assessment. Part 2 Practical guidance and examples of methods

2. For detailed risk analysis of **some critical components**, i.e. mainly related to radioactive species production, distribution and accumulation, the following failure analysis techniques are instead used:
   FMEA – FMECA
   HAZOP

SPES QSMS documents already available for the Safety Analyses

INFN Istituto Nazionale di Fisica Nucleare – Laboratori Nazionali di Legnaro | SPES exotic beams for science

SISTEMA DI GESTIONE PER LA QUALITA' E SICUREZZA DI SPES

Codice doc.	DOC_00000002	Analisi dei rischi del progetto SPES	Rev.	02
			Pag.	1 di 59

Contenuto Documento

Documento che descrive il progetto SPES e contiene gli elementi di riferimento (dati, calcoli…) utilizzati per la valutazione dei rischi del progetto SPES

Risk Analyses for the SPES project

SPES exotic beams for science

[GESTIONE PER LA QUALITA' E SICUREZZA DI SPES

Codice doc.	PRG_00000002	Metodologia per la valutazione dei rischi	Rev.	00
			Pag.	1 di 13

Contenuto Documento

…lizzata per la valutazione dei rischi del progetto SPES

Procedure for risk identification and ranking for the SPES project

5.3 METODOLOGIA DI VALUTAZIONE DEL RISCHIO IN FASE PROGETTUALE

Per la stima del rischio in fase progettuale viene utilizzato il seguente metodo di valutazione basato sulla combinazione data da probabilità di accadimento del danno e gravità del danno. La metodologia adottata fa riferimento alla metodologia indicata dalle norme ISO 12100:2010 e ISO 14121-2:2007 relative alla valutazione dei rischi per le macchine e viene applicata in maniera estensiva anche a apparati sperimentali e impianti che non rientrano nel campo di applicazione della direttiva 2006/42/CE (direttiva macchine).

Definiti **S** la gravità del danno, **P** la probabilità che l'evento pericoloso si verifichi, **F** la frequenza di esposizione al pericolo, **E** la possibilità di evitare o limitare il danno (evitabilità), il rischio **R** viene quantificato mediante la formula:

$$R = (P + F + E) \times S = C \times S$$

dove **C** è la probabilità che il danno si verifichi.

Determination of Risk level at design level following the procedure reported in the related documents already available for the QSMS

Severity level (S)	Occurrence Probability (P)												
	3	4	5	6	7	8	9	10	11	12	13	14	15
1	3	4	5	6	7	8	9	10	11	12	13	14	15
2	6	8	10	12	14	16	18	20	22	24	26	28	30
3	9	12	15	18	21	24	27	30	33	36	39	42	45
4	12	16	20	24	28	32	36	40	44	48	52	56	60

The RAD database: detailed analyses of SPES ISOL Front End

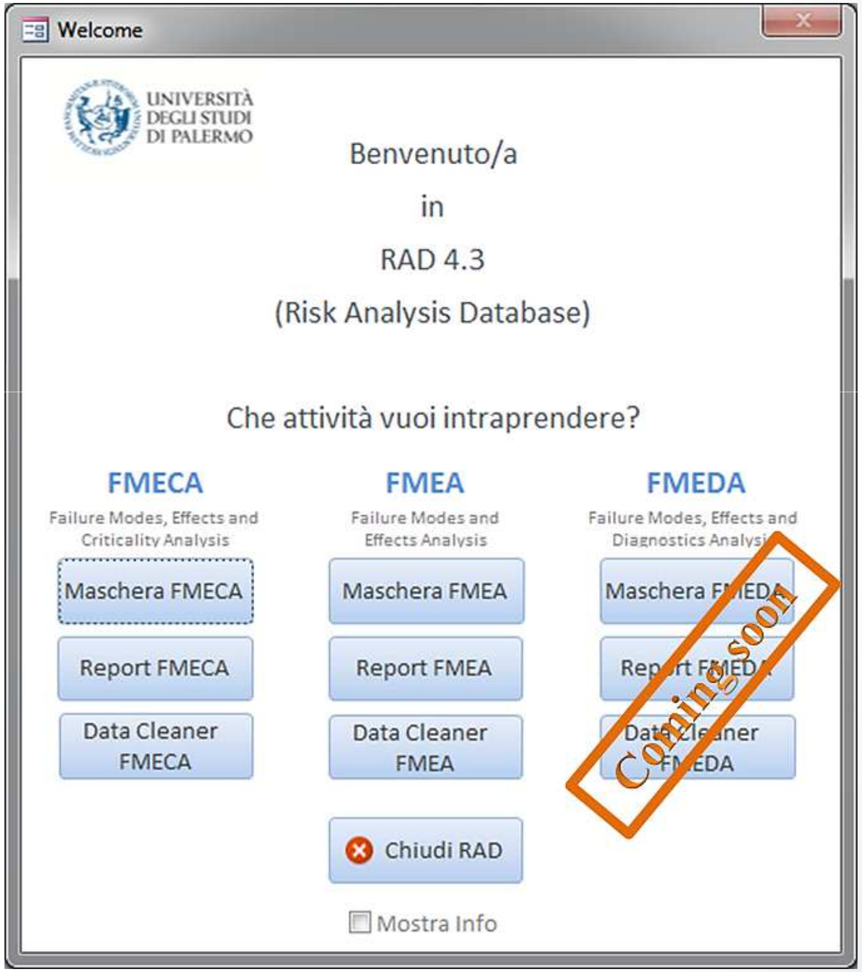
The RAD user interface

(DEIM Dept. -Palermo University)

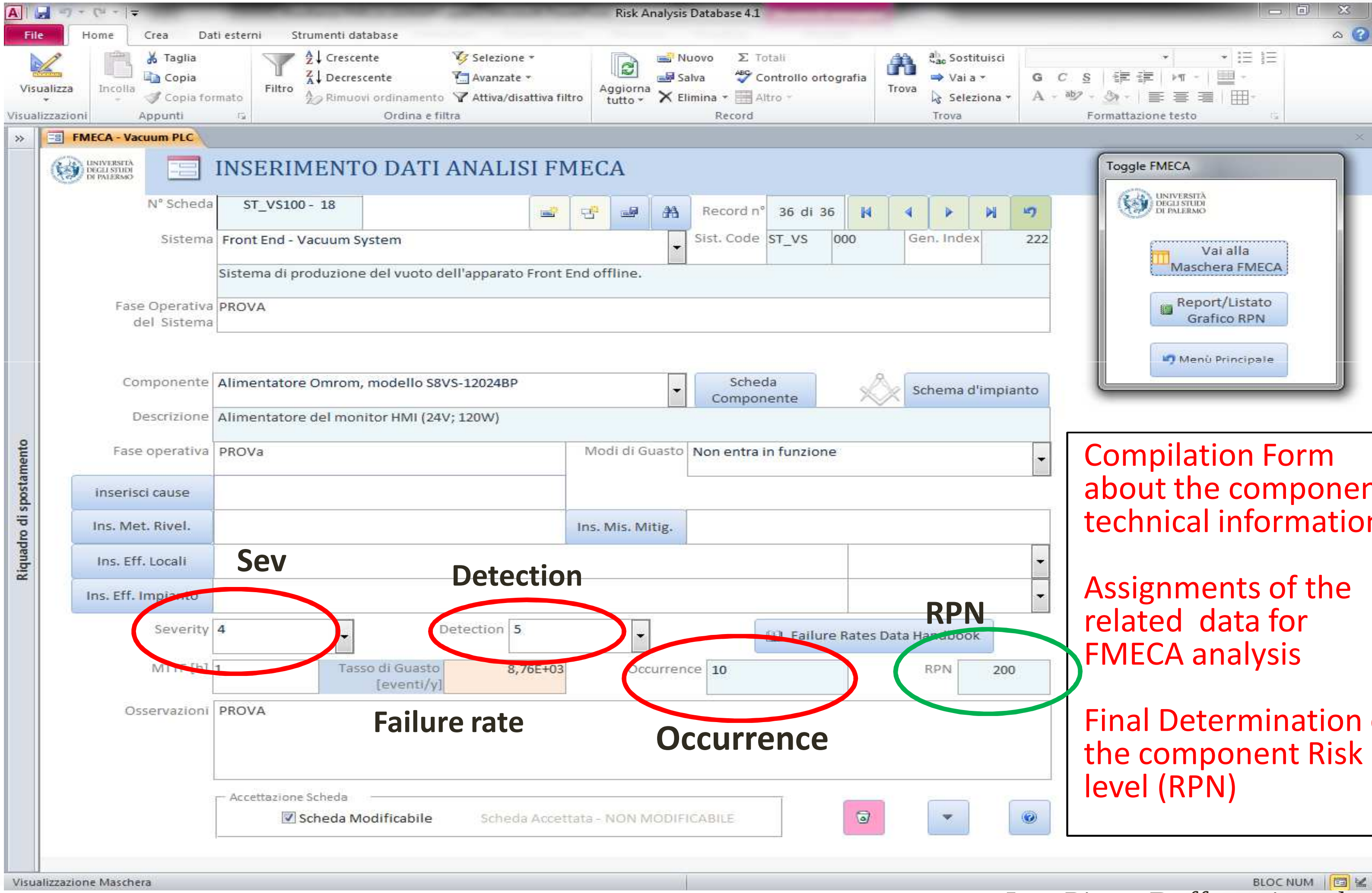
An example of database data entry using the FMECA analysis approach

Goal: determination of the RPN (Risk Priority Numbers)

- Severity (S)
- Severity X Occurrence (S X O)
  - Criticality
- Severity X Occurrence X Detection (S X O X D) = RPN



The RAD database:
data entry user interface



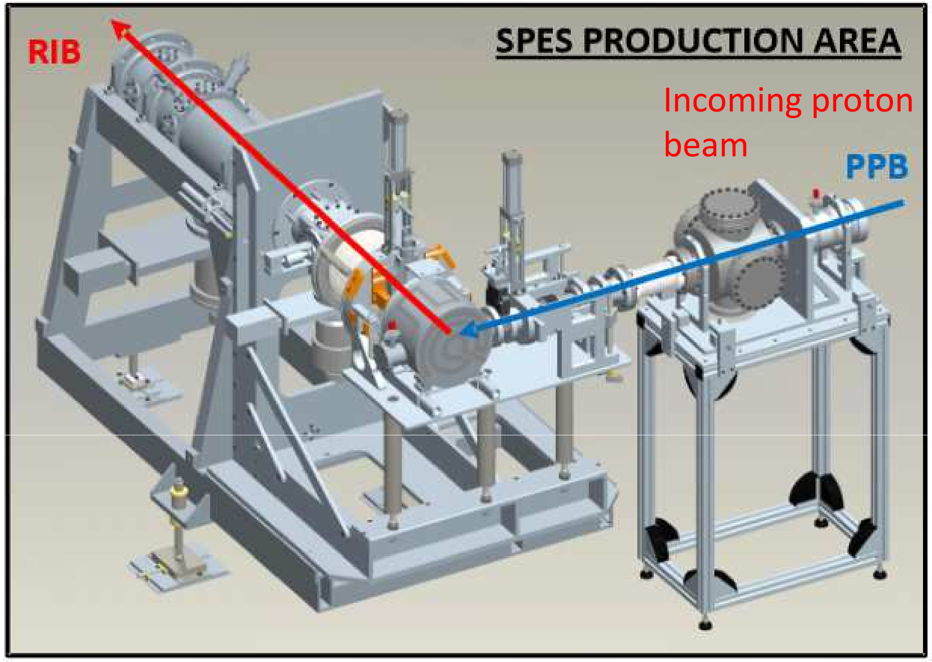
Compilation Form about the component technical informations

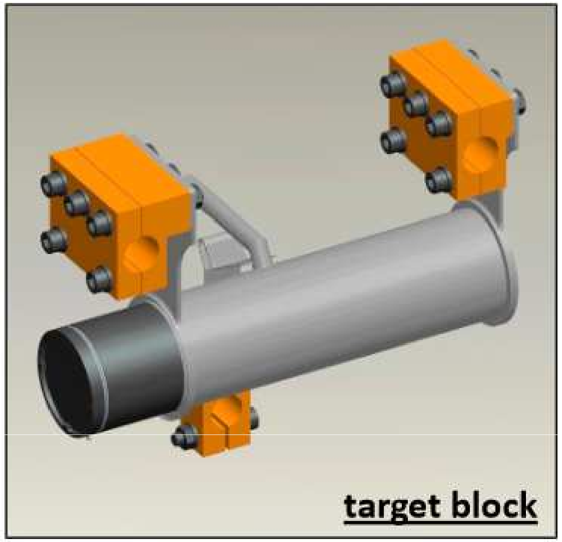
Assignments of the related data for FMECA analysis

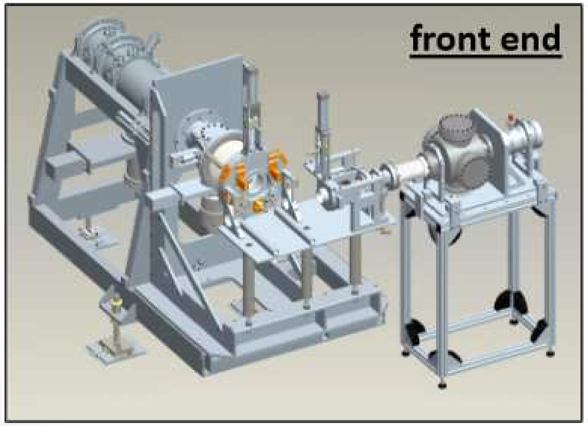
Final Determination of the component Risk level (RPN)

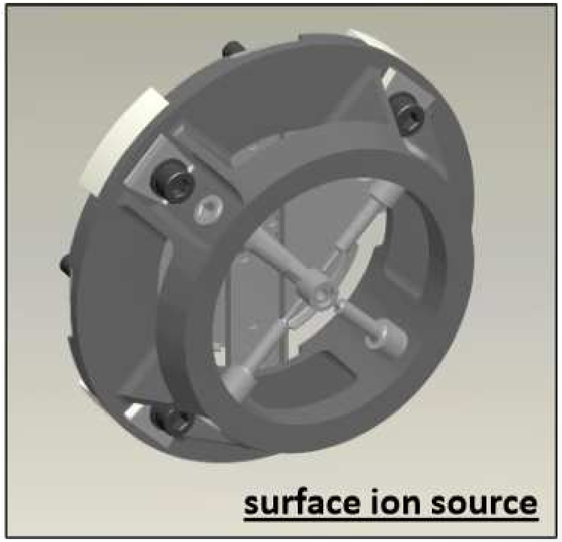
The SPES RIB Safety System

FMECA Analysis of the SPES ISOL target unit

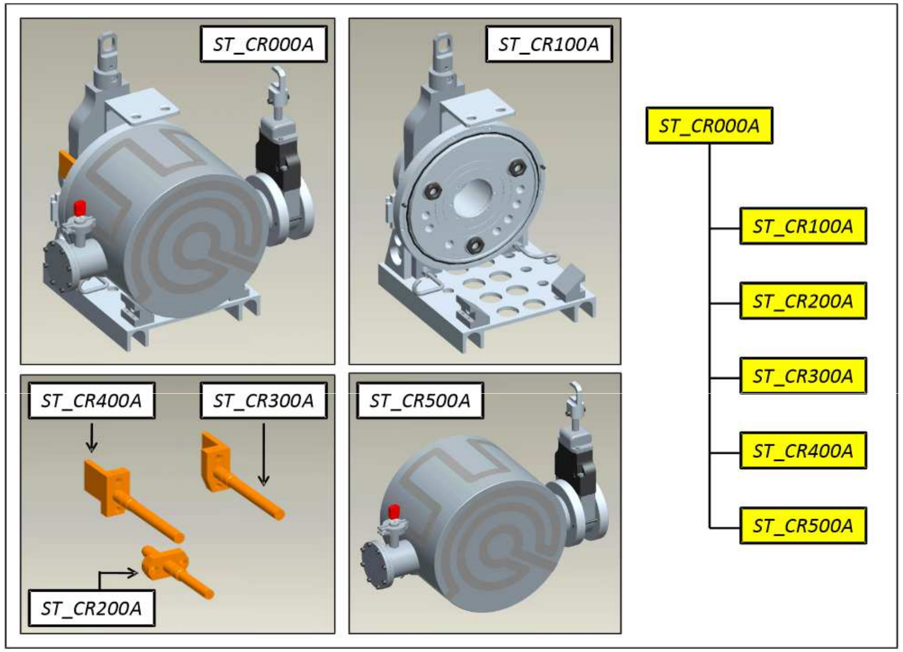


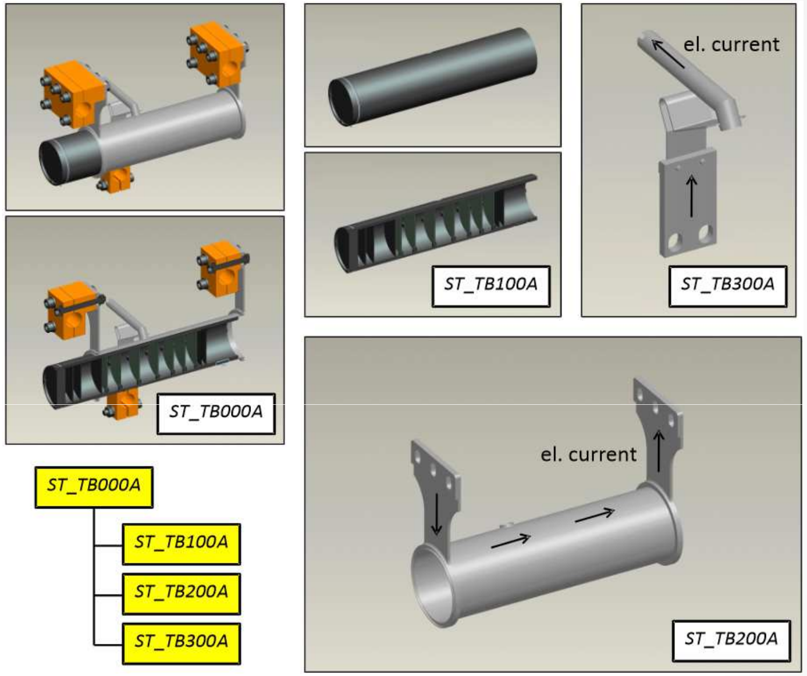


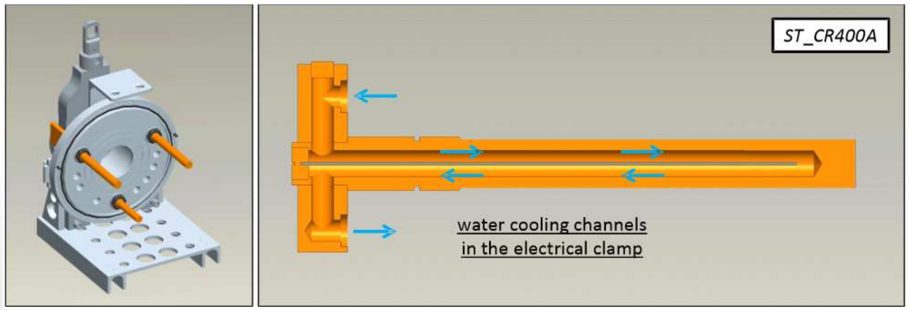




FMECA analysis of ISOL target







All ISOL Target components have been analyzed in details, taking into account Sub-assemblies.

Each one having its proper identification code

Main results from FMECA analysis

Front End system

a) **External leakage failure** of any of the vacumm lines' components (i.e. valves, vacuum gauges) due microcraks, or poor seal at the flange connections, would results critical. Impossible to continue operations, even using the redundant line, since the fault would quickly involve the entire system.

Action to be performed: An isolation valve added on both lines would remove the problem

b) **Spurious closure failure** : malfunctioning of the valves' pneumatic actuator, or actuator spurious electrical signal, during BEAM-OFF stages. In such a case the master PLC would force the vacuum system to an undue switching-off. The starting of the safety protocol would, indeed, override the target heating system as well as the HVPS.

Action to be performed: Modification of the control system logic on the scheduled operations in order to preserve the vacuum level instead, during the transient shutdown.

- **ISOL Target**

Electrical, water-cooled, clamping System, heating the SPES production target and the ion extraction source: a loss of coolant accident in a closed system would be extremely critical. Possible thermolysis of water, and following graphite oxidation of the target block. Hydrogen production in a closed high temperature environment possible.

Action to be performed: such a component should pass scheduled high pressure test first, before being used

Other SPES Critical systems under investigation

- ***Ventilation system***

  *The ventilation system is to be considered a key safety element, due to the presence of airborne contamination. The amount of **radioactive releases** is moreover heavily dependent on the system design.*

- ***Access System***

  *The system must ensure that they staff and users people are **trained**, **qualified** and **authorized** to access to the areas.*

- ***Handling system***

  Highly Radioactive and contaminant components (e.g. target) severely limit or prevent maintenance activities and the possibility to learn from failures

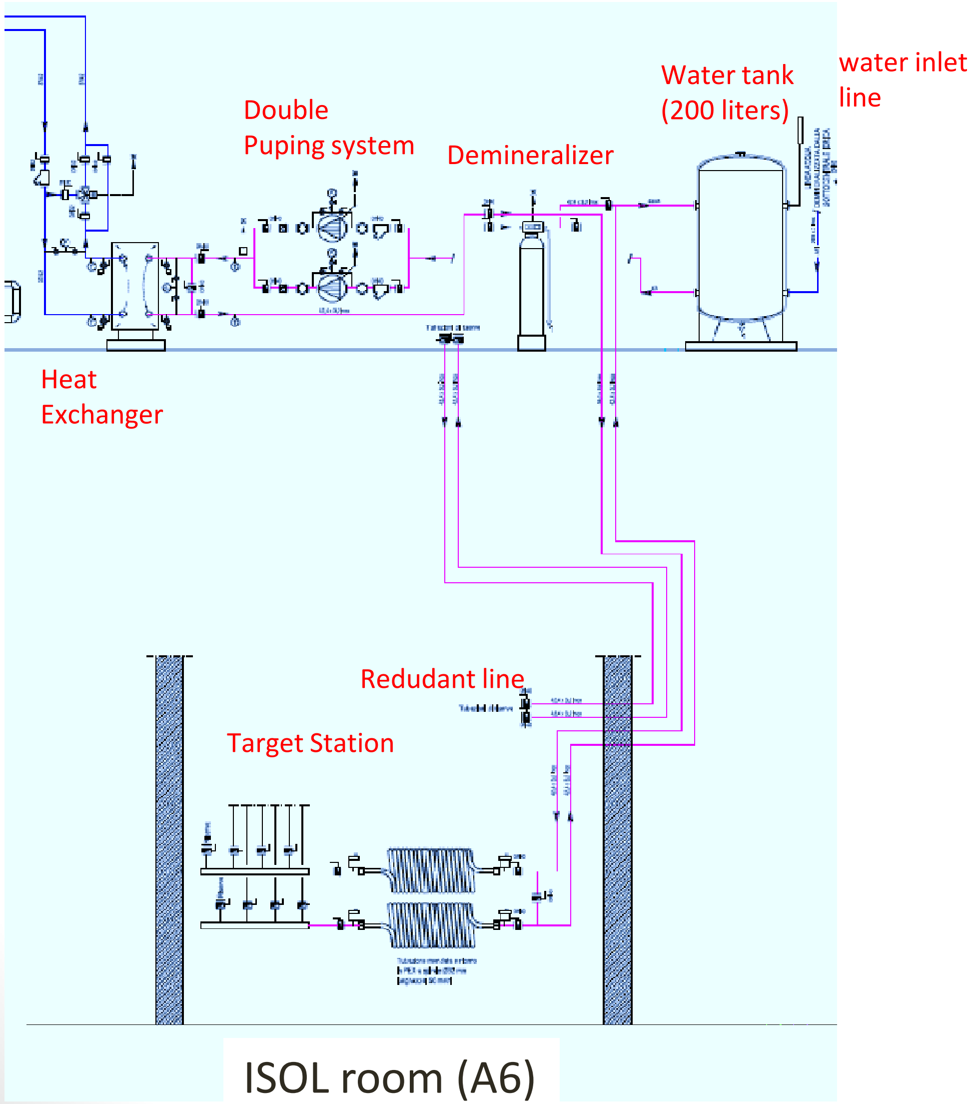
- ***Vacuum system***

  The vacuum system is permanently contaminated by mobile radioactivity. Venting and pumping produces volumes of radioactive gas and aerosols. Within the system, radioactive ion implants are produced in the form of open radioactive sources of not negligible activity which is a safety risk.

- ***Radioactive waste***

  SPES targets have a short lifetime. The ensuing amount of highly radioactive and potentially contaminant waste yearly produced calls for a careful planning and relevant budget allocations to be evacuated towards the nuclear waste repositories.

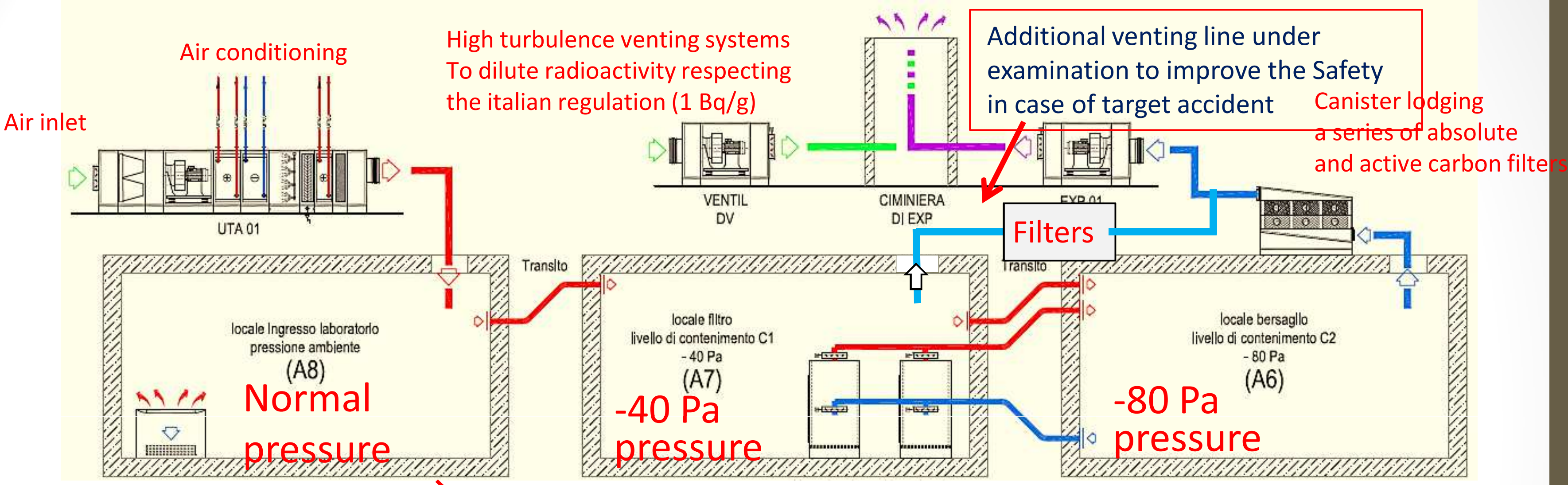
The ISOL target cooling system



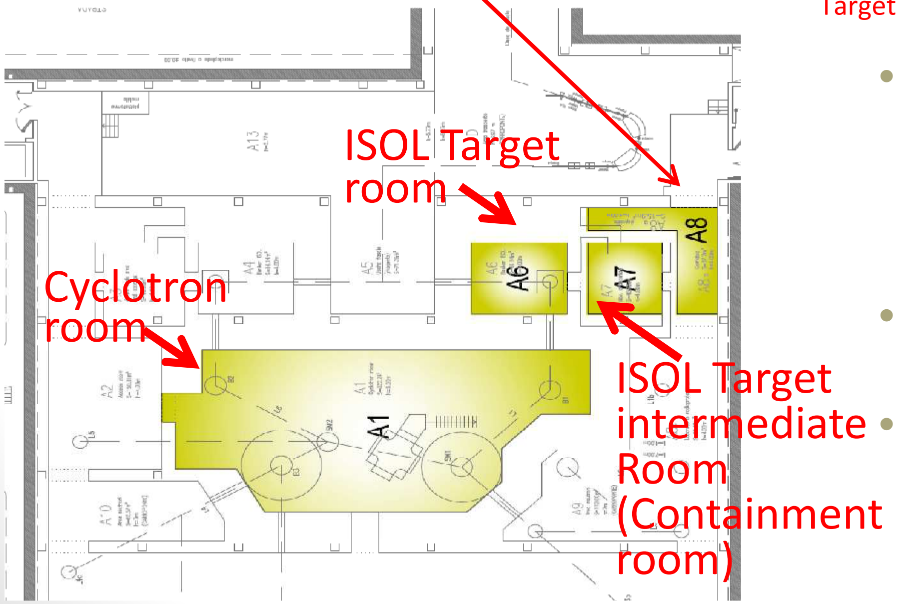
A Closed cooling circuit

- Demineralized water (0.5 μS/cm)
- Oversized circuit designed for 15 kW heat power removal (double than required)
- Heat power exchanged with the general cooling system of the SPES building
- Redundant pumping systems to avoid any pumps failure during operations
- ^{3}H production level expected under each SPES two-week run. Assessment of operation time allowed before contaminated water should be replaced

The ISOL target venting system



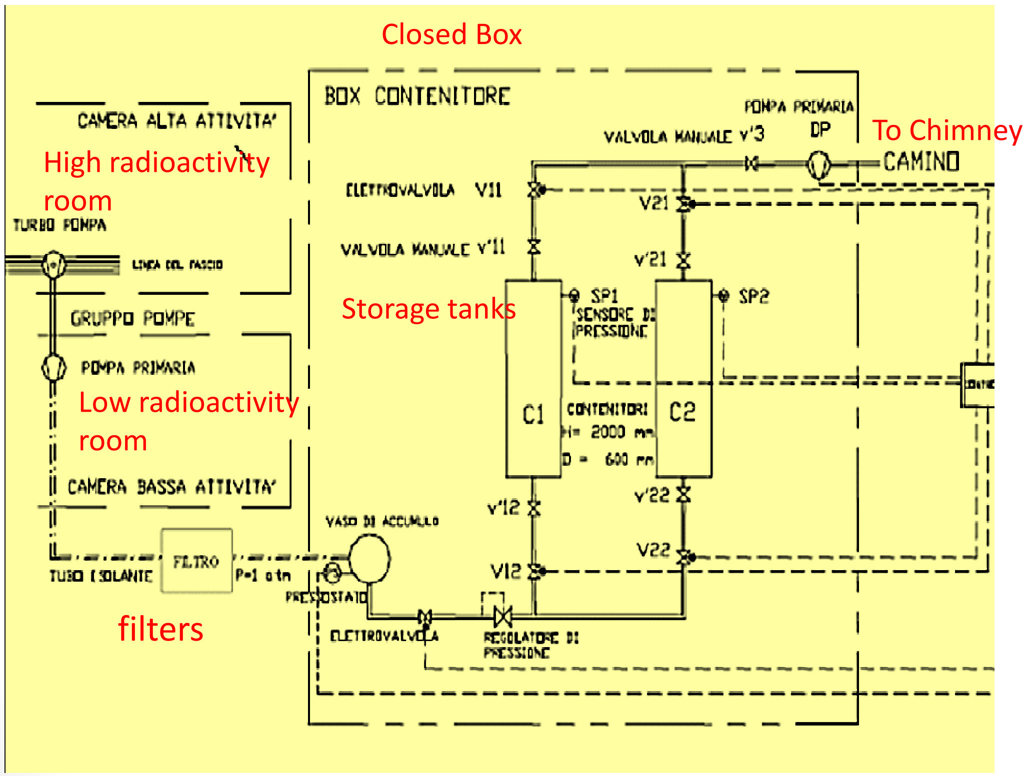
Target room air conditioniny redundand system



- Double room under increasing under pressure to get containment of possible radioactive release from target sytem and air activation durin facility running
- Cyclotron room is under pressure as well
- Safety analyses during possible accident sceniario are under way

The RIB's vacuum and storage system

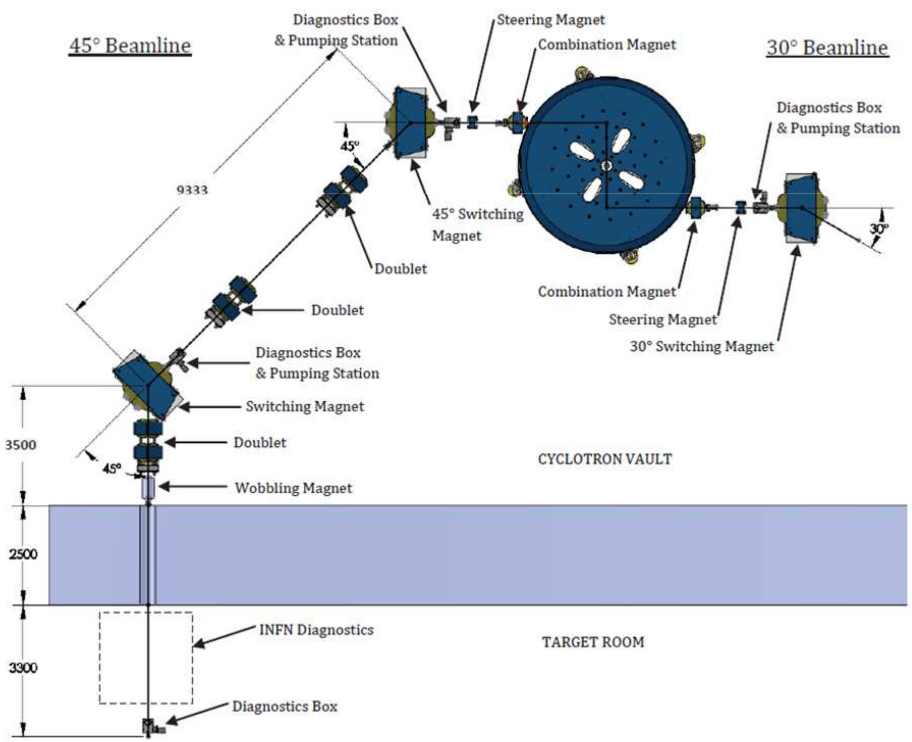
The EXCYT layout system at the LNS labs in Catania will will be our reference, although revised because of higher radioactivity production. Some consideration are under examinations from the analyses of TRIUMF and ISOLDE RIB's vs' as well



- **All the storage system under environment pressure**
- Outlet of baking and roughing pump both in the target area and downstream are stored in decay tanks before being delivered into the nuclear ventilation system
- All the outlet of primary pumps collected and let decay in filters ambient pressure.
- When the filter pressure reaches 0.8 bar, the gas is transferred to one of the two storage tanks (0.625 m^3 respectively).
- When one tank is full, the new produced gas is transferred to the second tank while the gas in the fist tank is stored for a few months before being delivered, in controlled way, into the nuclear ventilation system
- The gas **delivery into nuclear ventilation system is performed every ~ 3 months**

The Cyclotron Radiation Safety System

- Being the first part of SPES facility to be installed inside the building the *Radiation Safety System* (**RSS**) to get safe operation for the cyclotron commissioning will be necessary and ready



SSR will be made **up by three elements**:

- Access Control System (**ACS**) for gates, doors, rounds, emergency buttons and for the enable control signal to the primary proton driver
- Personnel Monitoring System (**PMS**), to enable/disable personnel access to different areas;
- Radiation Control System (**RCS**), to control radiation monitors and related data.

Conclusions

The SPES QSMS and RSS is under way, mainly for the most critical parts, basically:

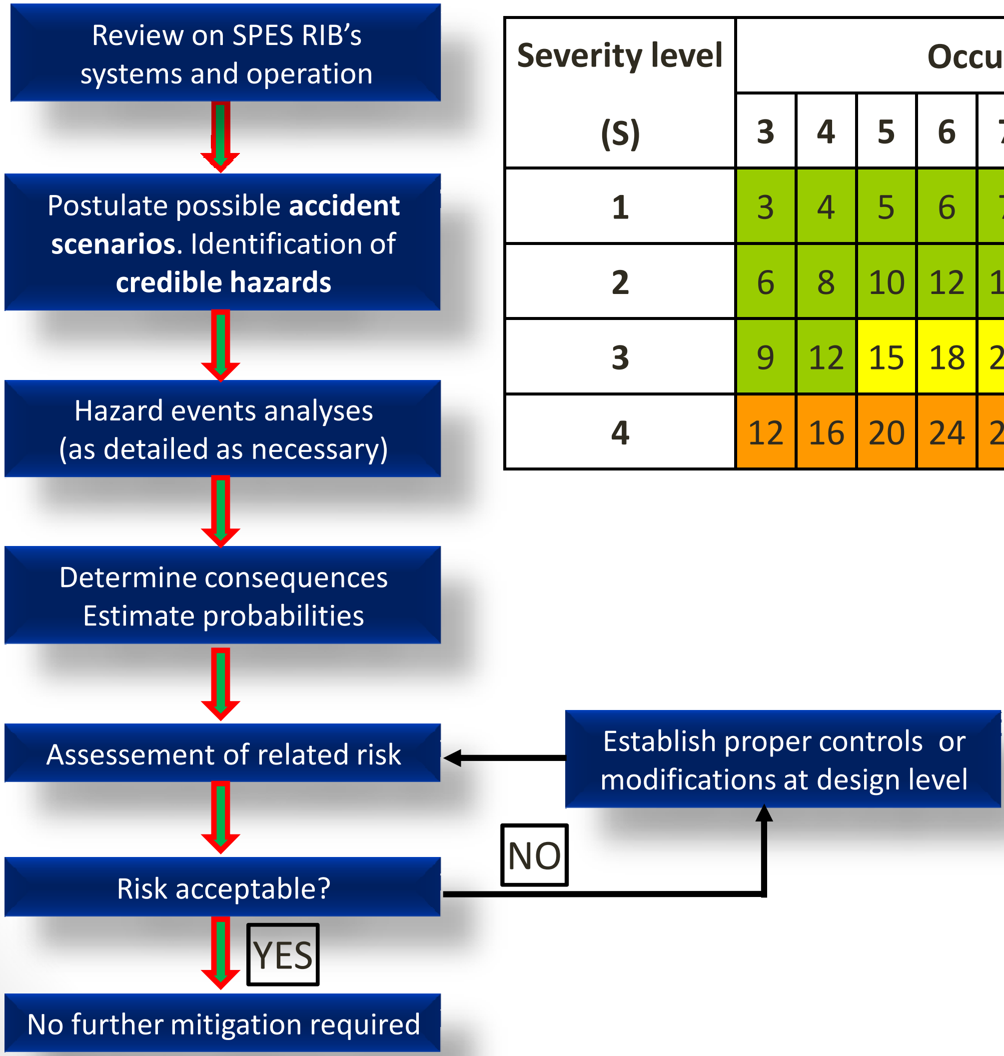
- the ISOL target system,
- the target cooling system
- the target room ventilation system
- the RIB's vacuum and storage system
- Contacts with italian companies for a full design of SPES safety system (SOGIN, NUCLECO, ENEL, ..)
- Support as well as indipendet examinations of the Safety of SPES project will therefore performed.

SPES Safety and Radioprotection group

- Demetre Zafiropouls
- Juan Esposito
- Lucia Sarchiapone
- Daniela Benini
- External Collaborations: (Nucl. Eng. Group Palermo University)
  - Pietro Buffa
  - Mariaosa Giardina
  - Francesco Castiglia

The End

Flow chart of the safety analyses approach and related Risk Matrix adopted



Severity level (S)	Occurrence Probability (P)												
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4	12	16	20	24	28	32	36	40	44	48	52	56	60

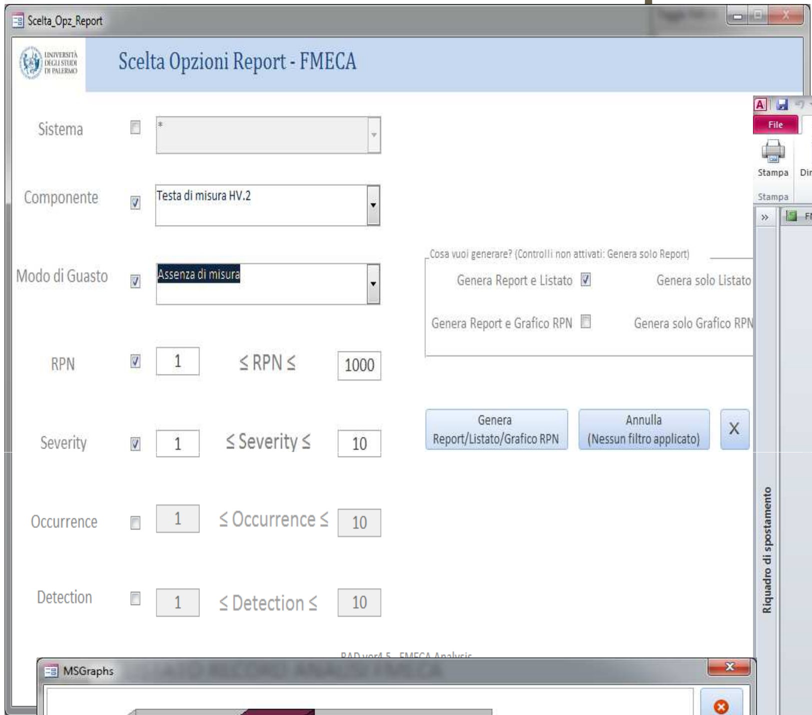
IMPACT
No Risk
Minor Risk
Manageble Risk
Unacceptable Risk

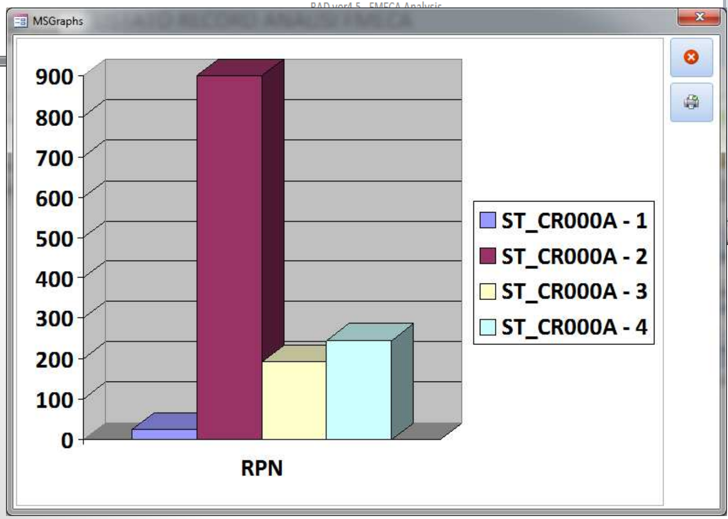
Each risk is to be evaluated according to the above Risk matrix.

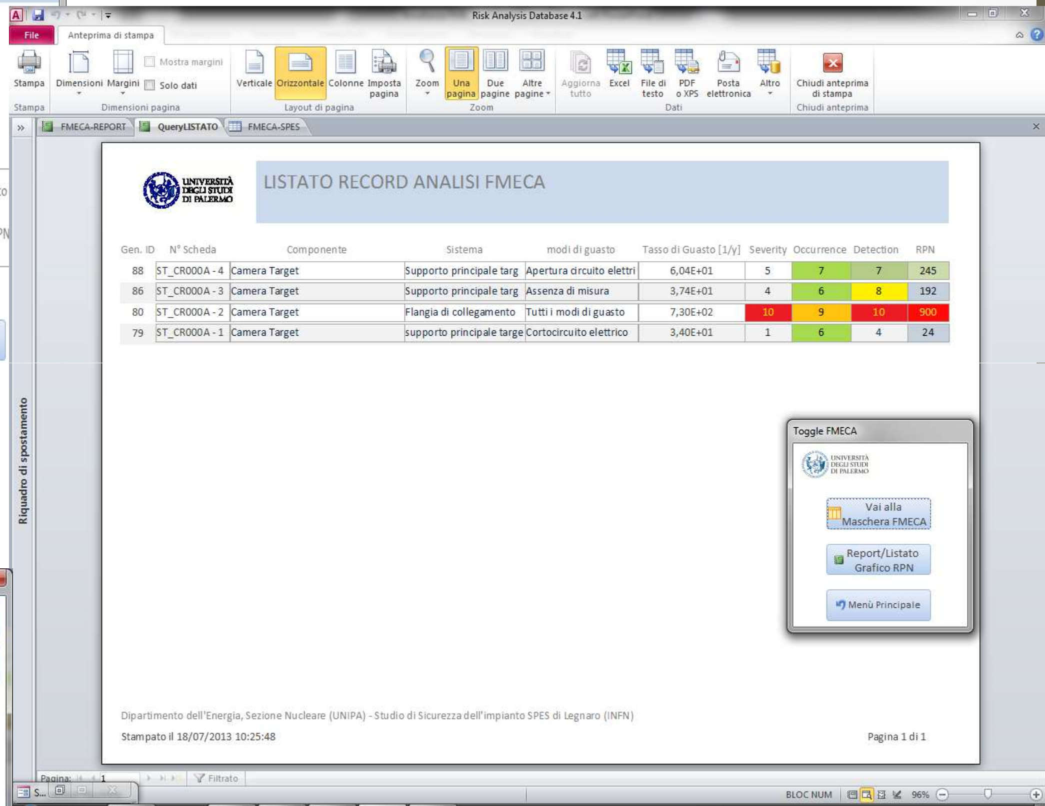
Numbers are related to the overall risk estimation, based on the framework of the Occurrence Probability and Severity Levels considered in the procedure reported in the SPES QSMS safety docs.

An agreed uniform terminology in technical discussions is therefore provided.

The RAD database: different user option to get FMECA results data

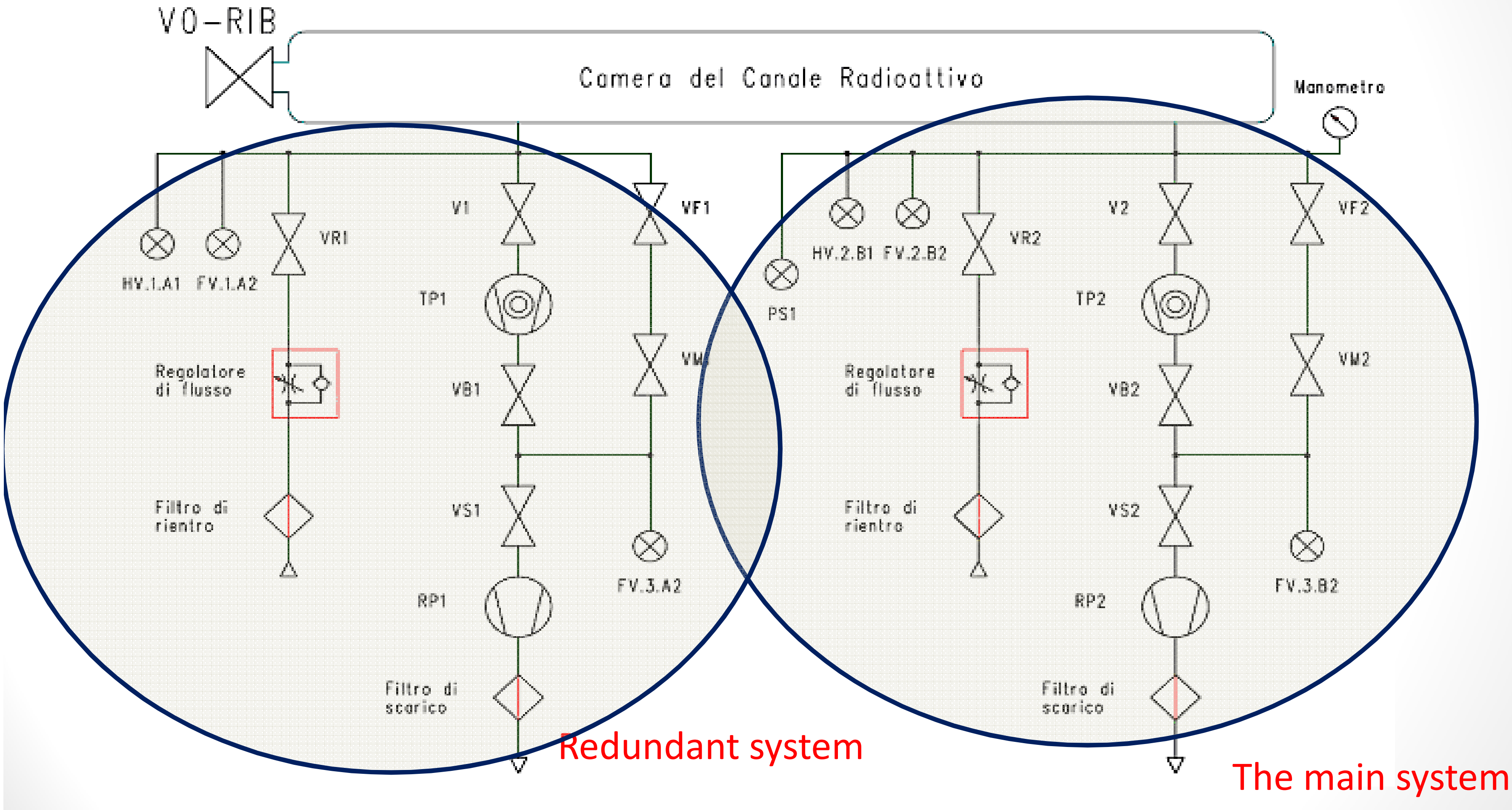






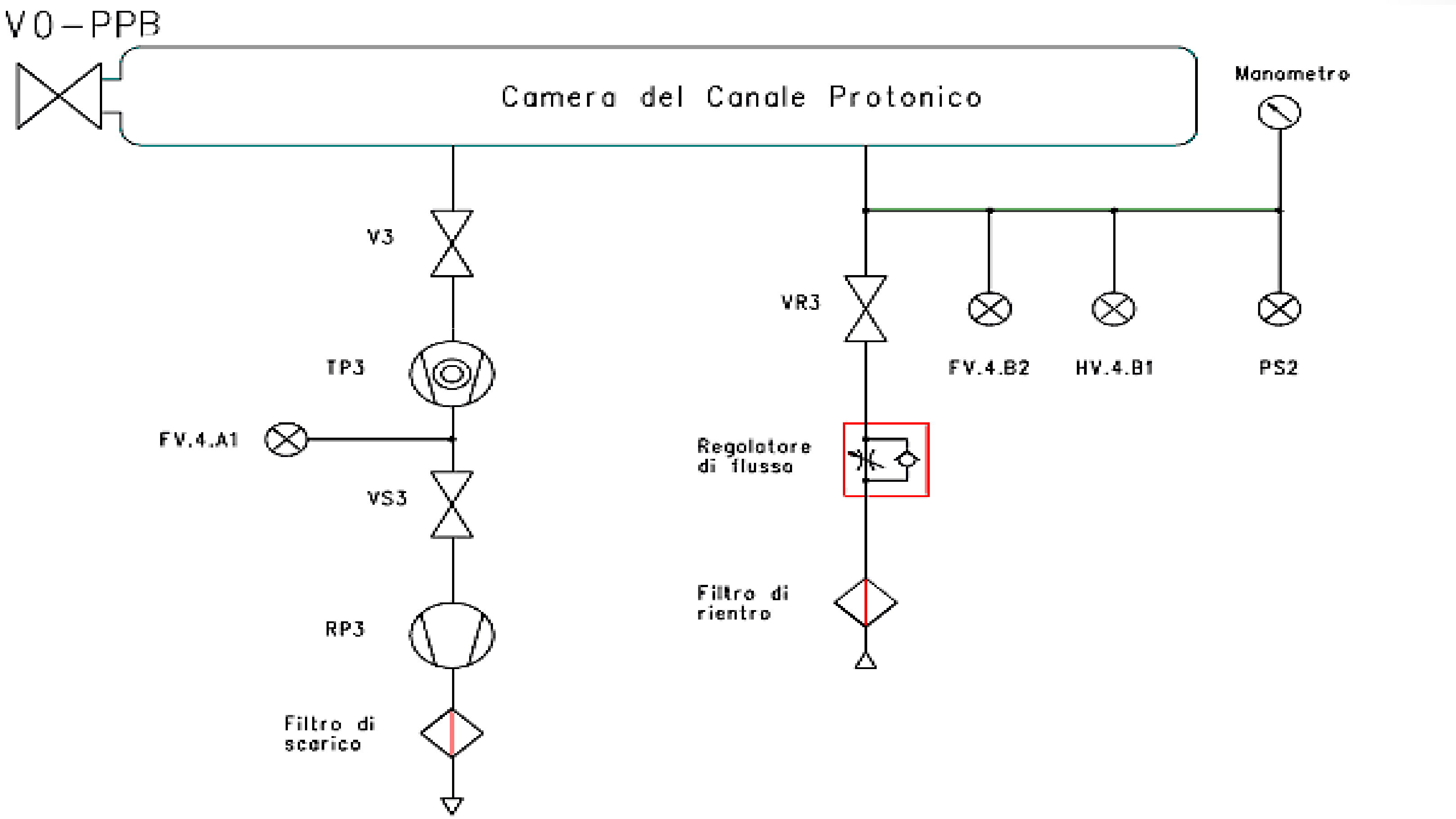
Starting point to act design modification in order to mitigate and/or remove design erros (i.e. Reduction of RPN number

Front-End vacumm system FMECA Analysis:RIB line (downstream the ISOL target)



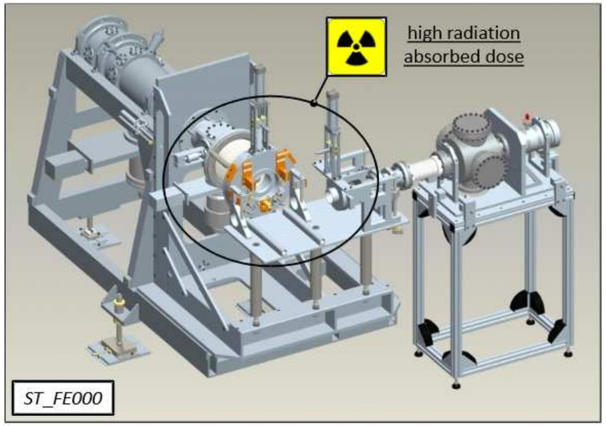
Main components of the RIB (Radioactive Ion Beam) vacuum system

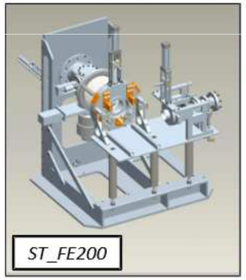
Front-End vacumm system FMECA Analysis: PPB line (upstream the RIB target)

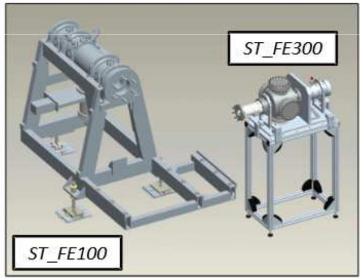


Main components of the PPB (Primary Proton Beam) line:

The SPES target Front End



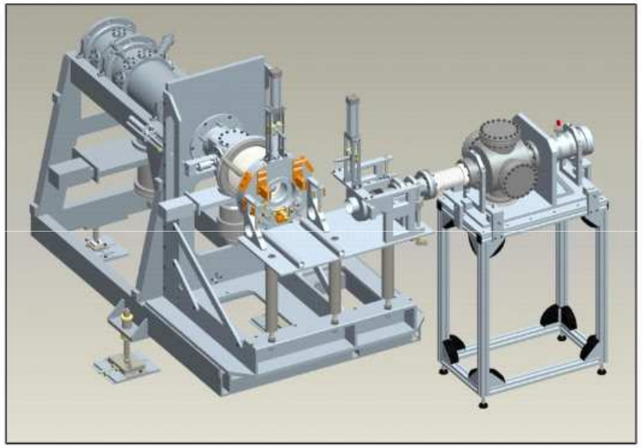


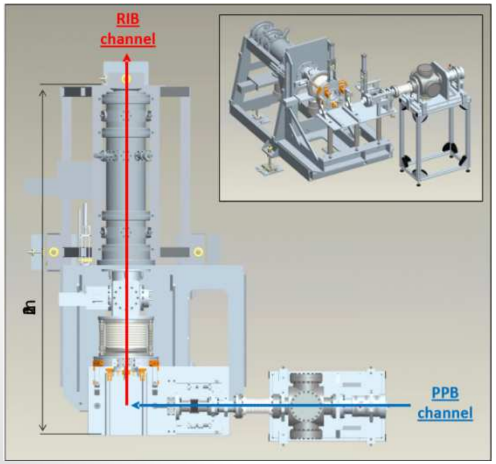


scheme
of the SPES front end
subassemblies

sublevel 0 / sublevel 1 / sublevel 2

- ST_FE000
  - ST_FE100
    - ST_FE110
    - ST_FE120
  - ST_FE200
    - ST_FE210
    - ST_FE220
    - ST_FE230
    - ST_FE240
    - ST_FE250
  - ST_FE300
    - ST_FE310
    - ST_FE320
    - ST_FE330
    - ST_FE340





All Front End system components have been analyzed in details, taking into account two-level Sub-assemblies.
Each one having its proper identification code