CERN
CH-1211 Geneva 23
Switzerland

EDMS NO.	REV.	VALIDITY
0000000	0.0	DRAFT

REFERENCE
AWK-EQCOD-XX-XXXX

Date: 2015-04-08

ENGINEERING SPECIFICATION

BTVs for proton and common beam line
PART OF WP 4

ABSTRACT:

This engineering specification summarizes all the engineering work done related to the BTV beam profile measurement system in the proton and common beam line that is part of AWAKE Project Work Package 4.

DOCUMENT PREPARED BY:	DOCUMENT TO BE CHECKED BY:	DOCUMENT TO BE APPROVED BY:
Bartolomej Biskup Stefano Mazzoni Stephane Burger	TBD	TBD

DOCUMENT SENT FOR INFORMATION TO:

[List of persons to whom the document is sent]

HISTORY OF CHANGES

REV. NO.	DATE	PAGES	DESCRIPTIONS OF THE CHANGES
0.0	2015-04-08	16	Initial submission

TABLE OF CONTENTS

1. PURPOSE AND SCOPE 4
2. ENGINEERING DESIGN 4
2.1 DETAILED DESCRIPTION OF THE SYSTEM/EQUIPMENT 4
2.2 TECHNICAL PARAMETERS 6
2.3 PRODUCT BREAKDOWN STRUCTURE AND CODING 7
2.4 LAYOUTS AND SCHEMATICS 8
2.5 CAD 3D-MOCK-UPS AND 2D-DRAWINGS 8
2.6 MANUFACTURING, ASSEMBLY AND TESTS 9
3. INTEGRATION AND INTERFACES 9
3.1 DIMENSIONAL REQUIREMENTS AND PARAMETERS 9
3.2 UTILITIES REQUIREMENTS AND PARAMETERS 10
3.3 INFRASTUCTURE REQUIREMENTS AND PARAMETERS 12
3.4 INSTALLATION REQUIREMENTS 12
3.5 COMMISSIONING REQUIREMENTS 13
4. ORAMS ASPECTS 13
4.1 OPERABILITY ASPECTS 13
4.2 RELIABILITY ASPECTS 13
4.3 AVAILABILITY ASPECTS 14
4.4 MAINTAINABILITY ASPECTS 14
4.5 SAFETY ASPECTS 14
5. MANAGEMENT ASPECTS 14
5.1 REVISED COST ESTIMATE 14
5.2 FUNDING AND BUDGETS ASPECTS 15
5.3 PRELIMINARY SCHEDULE 15
5.4 PROCUREMENT 16
6. RISKS 16

ANNEX **A1** [TITLE] ..... STAND ALONE DOCUMENT

1. PURPOSE AND SCOPE

This engineering specification summarizes **all the engineering work** done related to the beam transverse and longitudinal profile measurement system in the proton and common beam line that is part of AWAKE Project Work Package 4. More specifically, it describes the BTV system that has been engineered at system-level design; it lists the various **requirements** with respect to interfaces, integration with other systems and infrastructures, installation and commissioning; it summarizes the status with respect to management aspects such as cost, schedule and procurement.

2. ENGINEERING DESIGN

2.1 DETAILED DESCRIPTION OF THE SYSTEM/EQUIPMENT

In order to achieve a successful operation of the facility and evaluate its functionality, a precise beam diagnostics is crucial. The BTV system is used to measure a beam profile to ensure a proper beam size, transverse alignment of different beams and their synchronisation. This document deals with the BTVs installed in the proton and common beam line and describes their use as a beam transverse and longitudinal profile monitor (the electron line BTVs will be described in separate document).

The BTV system in general consists of a vacuum tank hosting a movable support that can accommodate several radiator screens. The particle beam traversing the tank and hitting the radiator produces light that is collected by a camera which is attached to the BTV support. In the AWAKE proton and common beam-lines three different BTV types are used, a standard BTVSPS, a standard BTVI (in the TT41 line setup with the specific screens called BTVG) and a new design BTV, based on the BTVI.

BTVI and the new tank have a rotative support accommodating two radiators and two empty positions. The BTVSPS can host three radiators and one empty position. The radiators considered for use in AWAKE are either OTR (optical transition radiation) or scintillating screens. A standard CCD camera is used for all the AWAKE BTVs. The different BTVs will be described in the following sections (2.1.1 – 2.1.5). Their overview is given in Table 3.

[Narrative description of the system/equipment including various sketches, figures, etc. this sub-section is likely to be used in the AWAKE Project Technical Design Report editorial work.]

2.1.1 BTVs for TT40

In the TT40 proton beam-line three BTVSPS tanks (BTV.400105, BTV.400222 and BTV.400343) are installed. They contain three screens: titanium (Ti), carbon (C) and Chromox (Alumina). The Ti foils are adequate for the nominal AWAKE operation and no modifications of the tanks or screens are needed.

2.1.2 BTVs for TT41

The proton beam profile in TT41 beam-line will be measured by five BTVI systems (BTV.410406, BTV.410706, BTV.411006, BTV.411906 and BTV.412035). They host Ti and C radiators. For the AWAKE operation the Ti screen will be used. No modifications are needed. Four of the tanks are already installed, the fifth one (BTV.412035) is ready for installation.

2.1.3 BTVs for common beam line upstream the plasma cell

Two BTVs will be installed in the common beam line upstream the plasma cell (PC), measuring the profile of the proton, electron and laser beams (see left part of Figure 1). A new tank had to be designed for both BTVs in order to minimize the distance between the radiator and the camera to collect sufficient amount of photons on the camera chip.

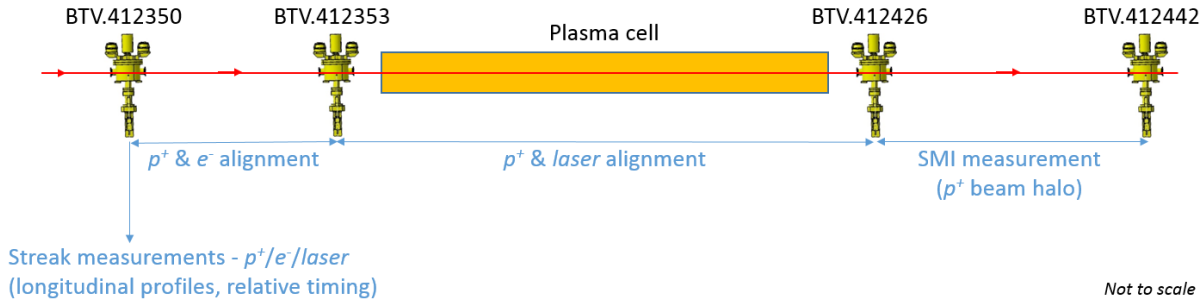

Figure 1 — The profile monitors in the common beam-line.

BTV.412350 will be used for the longitudinal profile (streak) measurement (see section 2.1.4) and for the alignment of p^+ and e^- beams (in coincidence with BTV.412353). These two BTVs should measure the transverse beam profile of both beams simultaneously, if reasonably possible (but it is not crucial).

Most suitable choice is a silicon (Si) screen coated by silver. This should produce enough OTR light for both the p^+ and e^- beams. A choice for the second (backup) screen is Chromox (Alumina) - only for e- beam in case of separate measurement - with much higher light yield.

The BTV.412353 will be also used for the p^+ and e^- beams alignment as mentioned above. The other measurement performed by this BTV is the alignment of p^+ and laser beams in coincidence with BTV.412426 (which is downstream the PC). Since the BTV.412353 has to be semi-transparent for the laser beam, a silica (SiO_2) screen coated by silver (thin semi-transparent layer) will be used. Chromox will be used as a second screen.

2.1.4 Streak measurements

The OTR light from the BTV.412350 screen can be redirected to the streak optical line by positioning of the flip mirror that is attached to the BTV support. The optical line passes through the trench in TT41 and through the core in the wall towards the enclosed optical table in TCV4/TSG41. The table is accommodated with filters and a streak camera on a movable support. The camera is able to measure the longitudinal profile of the beams and its main purpose is the synchronisation of all three beams.

2.1.5 BTVs for common beam line downstream the plasma cell

As mentioned in the previous section, the BTV.412426 (a standard BTVI) will be used for the p^+ and laser beams alignment in coincidence with BTV.412353. For this purpose a silicon screen coated by silver will be suitable. Another purpose of this system is a beam halo measurement in coincidence with BTV.412442. The difference between the intensity maximum in the centre of the beam and the halo edges is approximately three orders of magnitude. Therefore a standard OTR measurement is not possible. In order to achieve a measurable dynamic range on the camera, the beam core should be removed. One possibility is to drill a hole in the middle of the screen (in case of the scintillating screen the hole can be filled with an OTR screen with much lower light yield). Another option is to use a micro-mirror array, which can optionally redirect light from a defined area. Taking into account the low intensity of the beam halo, the preferred screen material is either Chromox or YAG (or a screen combining one or both of these materials with an OTR screen at the centre).

The most downstream BTV (BTV.412442) will be used for the p+ beam halo transverse profile measurement in coincidence with BTV.412426. For the measurement and the screen apply everything which was described above. Only difference is that this BTVSPS has three slots for screens. To increase flexibility, all three slots will be occupied by different screens, possibly a standard Chromox (to see clearly the beam core), Chromox with drilled centre (potentially filled by an OTR screen) and YAG with drilled centre (or combined screen, possibly combining three materials).

2.2 TECHNICAL PARAMETERS

The overall parameters of the BTVs are listed in Table 1.

Parameter		Unit	Value
Spatial resolution		μm	50
Typical frame rate		Hz	1-10
Field of view		mm x mm	20x20 – 100x71
Type of radiator:			
	TT40, TT41 line		OTR
	BTV.412350, BTV.412353,		OTR, scintillation, optical reflection for laser light
	BTV.412426, BTV.412442		OTR, scintillation
Type of source:			
	TT40, TT41 line		p^+
	BTV.412350, BTV.412353		p^+, e^-, laser
	BTV.412426, BTV.412442		p^+, e^-, laser
Streak measurement details:			
Temporal resolution (BTV.412350)		ps	[0.2 - 10]
Temporal window (BTV.412350)		ps	20-50-100-200-500-1000
Max. streak repetition frequency		Hz	100

Table 1 — General technical parameters for BTVs. For all BTV names, see Table 3.

2.3 PRODUCT BREAKDOWN STRUCTURE AND CODING

What follows is a general PBS for all BTVs.

PBS
1. Tank
1.1. vacuum chamber
1.2. vacuum chamber support
1.3. stepper motor or pneumatic actuator
1.4. screen support
1.5. OTR/scintillator screen
1.6. viewport
1.7. lamp for screen illumination
2. Imaging system
2.1. support for optical elements and camera (e.g. optical rail)
2.2. attenuation filters motor (e.g. filter wheel)
2.3. attenuation filters
2.4. single or multiple optical elements (lenses, mirrors)
2.5. camera
3. Data acquisition / control
3.1. power and data cables
3.2. BTV control card
4. Streak imaging system (BTV.412350 only)
4.1. flip mirror
4.2. single or multiple optical elements (lenses, mirrors)
4.3. optical line enclosure
4.4. streak camera system
4.4.1. optical Table
4.4.2. optical table enclosure
4.4.3. attenuation and colour filters
4.4.4. motors for filters positioning (e.g. filter wheel)
4.4.5. streak camera and power supply
4.4.6. motors for streak camera position control
4.4.7. local / remotely controlled fine delay unit
4.4.8. PC for streak camera control

Table 2 – General PBS for BTV systems.

[The PBS / Bill of Material, and the items and functional position codes provided to date. This subsection can consist of a table.]

2.4 LAYOUTS AND SCHEMATICS

The Table 3 summarizes the BTV names, their positions and basic description.

	Name	Centre (m)	EDMS #	Notes
TT40	BTV.400105	7.273	SPS8032021361	BTVSPS Already installed. No modifications needed.
	BTV.400222	37.92501		
	BTV.400343	95.43102		
TT41	BTV.410406	253.7582	SPSBTVG_0001 to SPSBTVG_0006 For rotative screen assembly LHCBTVI_0001	BTVG type. Already installed except for 412035. No modifications needed.
	BTV.410706	347.6584		
	BTV.411006	441.5586		
	BTV.411906	702.64915		
	BTV.412035	741.7792		
p+e+laser Before PC	BTV.412350	806.3455	Not available	New design based on BTVI type. Streak line
	BTV.412353	807.9985		New design based on BTVI type.
p+laser After PC	BTV.412426	821.3715	SPSBTVG_0001 to SPSBTVG_0006, LHCBTVI_0001	"BTVI" type. Reuse slightly irradiated one or procure new Development needed for beam halo optics.
	BTV.412442	829.5099	SPS8032021361	BTVSPS, in storage. New screen. Development needed for beam halo optics.

Table 3 – Layout names, position and EDMS numbers for BTVs.

[This sub-section shall list the various layouts, schematics, process/utility flow diagrams (PFDs/UFDs), pipe and instrumentation diagrams (P&IDs) input/output lists, etc. that were prepared and released in the engineering design phase. This material can be presented as a table; the corresponding EDMS nos. shall be provided.]

2.5 CAD 3D-MOCK-UPS AND 2D-DRAWINGS

Name	EDMS #	Maturity
BTV.400105	SPS8032021361	Drawings available for execution
BTV.400222		
BTV.400343		
BTV.410406	SPSBTVG_0001 to SPSBTVG_0006 For rotative screen assembly LHCBTVI_0001	Drawings available for execution
BTV.410706		
BTV.411006		
BTV.411906		
BTV.412035		
BTV.412350	Not available	At time of writing (April 2015), a new design based on the modification of the "BTVI" type is being developed by CERN design office. The design is in an advanced phase and is expected to be ready by May 2015 and approved by June 2015.
BTV.412353		

Name	EDMS #	Maturity
BTV.412426	SPSBTVG_0001 to SPSBTVG_0006, LHCBTVI_0001	Drawings available for execution
BTV.412442	SPS8032021361	Drawings available for execution

Table 4 – BTVs 2D-drawings.

[This sub-section shall list the 3D-mock-ups and 2D-drawings that were prepared and released in the engineering design phase. This material can be presented as a table; the corresponding EDMS nos. shall be provided.]

2.6 MANUFACTURING, ASSEMBLY AND TESTS

The TT40 and TT41 BTVs are installed (except BTV.412035 which is ready for installation). For these BTVs only a basic functionality check is needed. The BTV.412350 and BTV.412353 need to be manufactured and assembled and BTV.412426 and BTV.412442 will be refurbished (including production of new screens). If radiation protection authorities decide that BTV.412426 should not be used because of high residual dose, a new tank will have to be manufactured. For these four common beam line BTVs a functionality tests followed by cleaning, vacuum tests and fine screen alignment are needed.

[This sub-section shall list all the provisions considered with respect to the manufacturing, assembly and tests of the system/equipment and its components.]

3. INTEGRATION AND INTERFACES

3.1 DIMENSIONAL REQUIREMENTS AND PARAMETERS

The dimensions of the BTV tanks and their supports are provided in the EDMS documents listed in Table 3. All these systems are already integrated in the beam line layouts. For the dimensional requirements of the streak equipment see EDMS #1501342.

[This sub-section shall summarize all the **requirements** and **parameters** in term of **space** required to install, operate and maintain the system/equipment, including mechanical interfaces with neighbour systems and equipment.]

/!\ The content of this sub-section shall be prepared together with EN-MEF-DS (configuration management section) and EN-MEF-INT (integration section).

3.2 UTILITIES REQUIREMENTS AND PARAMETERS

3.2.1 CONTROLS AND COMMUNICATION

For the BTV control see CERN document CERN-AB-Note-2008-041-BI and for the stepping driver EDMS #1474436. The streak measurement will be controlled by a stand-alone computer placed in the rack next to the streak optical cable. When the access to the zone is not possible, the computer will be operated remotely through Ethernet.

[This sub-section shall summarize all the **requirements** and **parameters** in term of **controls**: accelerator controls, industrial controls, alarms, GSM/WIFI, fieldbuses, etc.]

/!\ The content of this sub-section shall be prepared together with BE-CO, EN-ICE, GS-ASE and IT-CO.

3.2.2 VACUUM

The vacuum requirements for the AWAKE beam lines (at the BTV positions in range of 10^{-8} to 10^{-6} mbar) are consistent with the BTV operation. For detailed specification of vacuum systems see EDMS #1410427.

[This sub-section shall summarize all the **requirements** and **parameters** in term of **vacuum**: bake-outs, sectorization, etc.]

/!\ The content of this sub-section shall be prepared together with TE-VSC.

3.2.3 AC AND PULSED ELECTRICAL POWERING

Only General Service for racks was requested by DIR document (EDMS #1481242).

[This sub-section shall summarize all the **requirements** and **parameters** in term of **electrical powering**: AC, pulsed, etc.]

/!\ The content of this sub-section shall be prepared together with EN-EL and TE-EPC.

3.2.4 CABLING

Cables for the first eight BTVs (which were used for CNGS operation) are already installed. For the new systems, six additional cables were requested by DIC document (4x NE48 and 2x NE12).

[This sub-section shall summarize all the **requirements** and **parameters** in term of **cables**: and cable pulling, incl. power cables, signal cables, optical fibres, etc.]

/!\ The content of this sub-section shall be prepared together with EN-EL.

3.2.5 CRYOGENICS

Cryogenics is not needed for the BTV systems.

[This sub-section shall summarize all the **requirements** and **parameters** in term of **cryogenics**.]

/!\ The content of this sub-section shall be prepared together with TE-CRG.

3.2.6 COOLING

Cooling is not needed for the BTV systems.

[This sub-section shall summarize all the **requirements** and **parameters** in term of **water cooling**: row water, demineralized water, chilled water.]

/!\ The content of this sub-section shall be prepared together with EN-CV.

3.2.7 VENTILATION

No special ventilation is needed for the BTV systems.

[This sub-section shall summarize all the **requirements** and **parameters** in term of **ventilation**.]

/!\ The content of this sub-section shall be prepared together with EN-CV.

3.2.8 COMPRESSED AIR

The compressed air was requested for the streak equipment as close as possible to the optical cable (location TCV4/TSG41).

[This sub-section shall summarize all the **requirements** and **parameters** in term of **compressed air**.]

/!\ The content of this sub-section shall be prepared together with EN-CV.

3.2.9 ALIGNEMENT AND GEODESY

The BTV tanks have their own alignment system (see the drawing documents in Table 3). A standard BTV alignment procedure is defined and followed.

[This sub-section shall summarize all the **requirements** and **parameters** in term of **alignment and geodesy**.]

/!\ The content of this sub-section shall be prepared together with EN-MEF-SU.

3.3 INFRASTUCTURE REQUIREMENTS AND PARAMETERS

3.3.1 CIVIL WORKS

In order to transport the OTR light to a radiation safe location where a streak camera could be located a core connecting TT41 and TCV4 and a trench in TT41 were requested. The cylindrical core has a diameter of 300 mm and its centre is 250 mm below the TT41 floor. The trench is constructed across the TT41 as a continuation of the core (for the detailed drawing see EDMS #1502268). Drilling to the TT41 floor is needed to attach the BTV supports.

[This sub-section shall summarize all the **requirements** and **parameters** in term of **civil works**.]

/!\ The content of this sub-section shall be prepared together with GS-SE.

3.3.2 METALLIC STRUCTURES AND SUPPORTING DEVICES

Each BTV has a defined support (see the drawings in Table 3). No additional structures are needed.

[This sub-section shall summarize all the **requirements** and **parameters** in term of **metallic structures and supporting devices**.]

/!\ The content of this sub-section shall be prepared together with EN-MEF and EN-MME.

3.3.3 HANDLING MEANS

Transport service will be used for the equipment transport to the AWAKE area and installation.

[This sub-section shall summarize all the **requirements** and **parameters** in term of **handling means**: transportation vehicles, cranes, etc.]

/!\ The content of this sub-section shall be prepared together with EN-HE.

3.4 INSTALLATION REQUIREMENTS

The equipment transported by the transport service to the final location will be installed by BI. (Is it true?)

[This sub-section shall summarize all the **requirements** and **parameters** in term of **installation**: (preliminary) installation procedures, scaffoldings, transportation routes, services available for installation, etc.]

/!\ The content of this sub-section shall be prepared together with EN-MEF-OSS (installation organization and scheduling section).

3.5 COMMISSIONING REQUIREMENTS

Functionality tests of the BTVs and the streak line alignment will be performed after installation. Low power mode for laser must be assured during this phase. The laser interlock has to be also tested.

[This sub-section shall summarize all the **requirements** and **parameters** in term of **commissioning**: (preliminary) hardware commissioning procedures, services required for commissioning, etc.]

/!\ The content of this sub-section shall be prepared together with BE-OP and EN-MEF-OSS (installation organization and scheduling section).

4. ORAMS ASPECTS

The BTV system is well established in the whole CERN accelerator chain. Its good operability, reliability, maintainability and safety has been verified within years of smooth operation in various particle beams with different energies. During the AWAKE operation no exceptional conditions are expected which could pose a risk on BTV system functionality. For the most delicate parts of the BTV, i.e. the radiator screens, spare parts are ordered. The standard CCD cameras (not radiation hard) can be easily replaced in case of radiation damage.

4.1 OPERABILITY ASPECTS

[This sub-section shall summarize constraints in term of **operations** and **operability**. If (preliminary) operations strategies and approaches were worked out, they shall be given in this sub-section.]

4.2 RELIABILITY ASPECTS

[This sub-section shall summarize constraints in term of **reliability** of the system/equipment. If reliability analyses were performed, they shall be listed in this sub-section.]

4.3 AVAILABILITY ASPECTS

[This sub-section shall summarize constraints in term of **availability** of the system/equipment. If availability analyses were performed, they shall be listed in this sub-section.]

4.4 MAINTAINABILITY ASPECTS

[This sub-section shall summarize constraints in term of **maintenance** and **maintainability**. If (preliminary) maintenance strategies and approaches were worked out, they shall be given in this sub-section.]

4.5 SAFETY ASPECTS

[This sub-section shall lists specific aspects related to **Safety**. This sub-section shall provide material that is to be used for the editorial work of the **safety file** of the facility being built or upgraded.]

5. MANAGEMENT ASPECTS

5.1 REVISED COST ESTIMATE

Device	description	cost [kCHF]
BTV.400105	no activity	0
BTV.400222	no activity	0
BTV.400343	no activity	0
BTV.410406	no activity	0
BTV.410706	no activity	0
BTV.411006	no activity	0
BTV.411906	no activity	0
BTV.412035	installation	1
BTV.412350 BTV.412353	design	20
	tank production	80
	screens	6
	BTV + streak line optics	10
	streak line table	5
	streak accessories (PC, scope,delay unit)	15
	optics line accessories (enclosures etc)	5
BTV.412426	refurbishment / new production (pending RP decision)	2 / 20
	screens	2
	screen support (if special screen for beam halo is needed)	1
BTV.412442	refurbishment (1 week FSU)	2
	screens	3

Device	description	cost [kCHF]
	screen support (if special screen for beam halo is needed)	1
general	cabling	10
general	crates	10
general	racks	?
	total	173/191

Table 5 – BTV cost estimate.

[This sub-section shall provide a revised cost estimates for the remaining of the development of the system/equipment. This revised cost estimate shall be compared with the one provided with the Work Package Description document released at the end of the Study Phase of the project.]

5.2 FUNDING AND BUDGETS ASPECTS

Budget shall come from CERN budget code 64940 (AWAKE Beam Instrumentation).

[This sub-section shall recall how the development of the system/equipment is to be funded: CERN budget and budget codes, in-kind contributions, external funding, etc. A particular attention shall be paid on the services to be requested (see § 3) and on their funding.]

5.3 PRELIMINARY SCHEDULE

Device	Planning
BTV.400105	N/A
BTV.400222	
BTV.400343	
BTV.410406	N/A
BTV.410706	
BTV.411006	
BTV.411906	
BTV.412035	Before July 2015

Device	Planning
BTV.412350	Design ready by May 15; approved by June 15; Parts ready by Oct 15; Assembly ready by Dec 15; Vacuum test Jan 2015; **Installation end Feb 16**
BTV.412353	
BTV.412426	Check with RP by April 15, refurbish by July 15, vacuum test by Sep. 15. **Installation Oct 15**
BTV.412442	Check and refurbish July 2015, vacuum test Sep 15; **installation Oct 15. Beam halo screen?**

Table 6 – Preliminary schedule.

[This sub-section shall provides a preliminary coordination schedule for the remaining of the development, the installation and the commissioning of the system/equipment.]

/!\ The content of this sub-section shall be prepared together with EN-MEF-OSS (installation organization and scheduling section).

5.4 PROCUREMENT

[This section shall briefly described the procurement strategy for the system/equipment.]

6. RISKS

[This section shall present in the form of a mini-risk register which were the risks perceived by the holders of the work package or part of the work package and how these risks were mitigated (Response column). Responses shall typically refer to the paragraphs were appropriate the provisions are featured.]

/!\ This sub-section can be prepared with the help of EN-MEF-QOP .

Table 7 — Summary risk register.

Risk	Response